

HOW DOES CHANGING TECHNOLOGY AFFECT STUDENTS NOTE-TAKING

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Abstract

In recent years, technology has improved and become a significant aspect in the classroom. Using technology has become a popular method of note-taking. This study investigates the effects of technology on note-taking by looking at the changes that can be shown between the traditional note-taking and taking notes by using different devices, such as the iPad and a smart pen. Modern technology, such as the smart pen which provides an automatic audio recording might improve student focus on important details. In addition, providing a standard note set along with note-taking tools such as an iPad might help student organize and access their notes. The result of this study showed that for all but one of the students, using technology did not affect their note-taking style or the amount of information in their notes. However, students were not satisfied with their notes when taken on the iPad.

Table of Contents

List of Figures	v
List of Tables	vi
Acknowledgements	vii
Chapter 1 - Introduction and Background	1
What is Note-taking?	1
Strategies of Note-taking	2
Technology for Note-taking.....	4
What is a Smart Pen and How Does it work in Note-taking	4
What is the iPad and How Does it work in Note-taking.....	6
Research Questions.....	7
Chapter 2 - Methodology	9
The Environment	9
Interview Questions	10
The Layout.....	11
General Codes.....	11
Mathematical Codes.....	13
Additional Analysis	15
Limitations	16
Chapter 3 - Results.....	18
Analysis of the Notes	19
General Analysis.....	19
Mathematical Analysis.....	24
Additional Analysis	28
Summary of the Student Experiences.....	32
Student 1 profile.....	32
Student 2 profile.....	35
Student 3 profile.....	38

Student 4 profile.....	40
Student 5 profile.....	41
Chapter 4 - Conclusion	43
Discussion.....	44
Future Research	45
References.....	47
Appendix A - Interview Questions	49
Appendix B - Responses to Questions 1 – 14.....	50
Interview 1	50
Interview 2	53
An Extra Interview with Student 2 after I Looked at his Notes.....	55
Interview 3	56
Interview 4	59
Interview 5	60

List of Figures

Figure 1.1 The Smart Pen Design.....	5
Figure 1.2 Typing or Writing on an iPad.....	6
Figure 2.1 The Unique Diagram in the Notes.....	14
Figure 3.1 The First Page from Student 2' Notes that Taken from Lecture 2	23
Figure 3.2 The First Page from Student P&P' Notes that Taken from Lecture 2.....	23
Figure 3.3 The First Page from Student 3' Notes that Taken from Lecture 2	24
Figure 3.4 A Picture of Doodles Taken from Student 2's notes.....	38
Figure 3.5 A Picture of Notes Taken by Typing on the iPad.....	39
Figure 3.6 A Picture of Notes Taken by the Traditional Style	39

List of Tables

Table 1.1 Examples of Abbreviations in Math Class	3
Table 3.1 Student Information	18
Table 3.2 The Number of Statements	19
Table 3.3 The Number of Keywords in the Notes	20
Table 3.4 The Number of Main Ideas in the Notes.....	21
Table 3.5 The Number of Student Ideas	22
Table 3.6 The Length of Notes for Each Lecture	22
Table 3.7 The Number of Justifications (Examples)	25
Table 3.8 The Number of Justifications (Proofs).....	25
Table 3.9 The Number of Theorems.....	26
Table 3.10 The Correctness of Diagrams	27
Table 3.11 The Number of Abbreviations	27
Table 3.12 Analyzing Old Notes for Student P&P.....	28
Table 3.13 Analyzing Old Notes for Student 1.....	29
Table 3.14 Analyzing Old Notes for Student 2.....	30
Table 3.15 Analyzing Old Notes for Student 3.....	30
Table 3.16 Analyzing Old Notes for Student 5.....	31
Table 3.17 The Old and the New Notes for Student 1	32
Table 3.18 Examples of Using the Recording Feature in Different Classes	33
Table 3.19 The Old and the New Notes for Student 2.....	36
Table 3.20 The Number of Doodles between the Old and the New Notes in Student 2 Notes	37
Table 3.21 The Old and the New Notes for Student 3.....	40
Table 3.22 The Old and the New Notes for Student 4.....	41
Table 3.23 The Old and the New Notes for Student 5.....	42

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Chapter 1 - Introduction and Background

Technology can play a significant role in education. Technology experts have been competing to make devices that are helpful in the education field. In recent years, students can carry in their backpack either a laptop, a smart phone, a smart pen, or an iPad. Students use these devices in classrooms for many uses. One of the most important tasks these devices can do in the classroom is note-taking.

What is Note-taking?

Note-taking is the ability to write down the basic information from a lecture. That information includes the key words and the main ideas to help students to remember and understand the lecture when they read the notes later. “Notes serve as an extension of our long-term memory” (Boyle, 2001). Note-taking is a very important task not only in university or school classes, but in also different fields. Notes can be taken by audience members who attend an oral presentation for any subject, or journalists who listen to an interview. Note-taking can be a part of the daily life for any person, any subject, any field, and any purpose. For students note-taking is an important skill in their studying as students and in their careers as professionals (Boyle, 2011). Good notes should include enough written material from the board and the instructor’s comments so that the student will be able to use the notes to understand the new ideas and the new concepts. Writing notes should not disturb the students’ attention or students’ understanding of what the instructor says. Although, it can be a complex task for students to meet all of these conditions, some students can produce high quality notes if they are able to meet all of these conditions and combine them effectively.

The purpose of taking notes in the lecture is to: (a) play a role as a helping factor in understanding the information, and (b) work as reference material for later study (Boyle, 2001). Students who cannot remember all the information that is presented in the lecture need to take notes. For these students, taking notes can play a significant role in studying and doing assignments as well. In contrast, some students prefer to listen actively during the class without taking any notes. They may believe that studying from the book is better since everything is written there in more detail. These students might not have the ability to effectively combine writing the notes, listening to the presentation, and understanding the new materials.

Strategies of Note-taking

In order to have good notes, students should have good strategies for taking notes. Following good strategies produces well written notes. Notes which everybody can read and understand are great notes. Students have to take notes that they can read later when they need them, otherwise some of the purpose of the note-taking task is lost. “Evidence from several decades of research emphasizes the importance of taking complete lecture notes and of reviewing them” (Pardini, Domizi, Forbes, & Pettis, 2005). If students can recognize the cues that identify key words and the main concepts in the lecture, they can write good notes, so “different cues produce different notes” (Huxham, 2010).

Students in university classes are expected to know how to take notes since they should have been taking notes for many years. Hopefully, the practice of writing notes during these years gave them strategic knowledge of note-taking and the ability to write great notes.

I define the strategies of note-taking that I wish to study as: (a) identify the main ideas and the keywords and make sure you have them in your notes, (b) add your own ideas, if possible, (c) be aware of the goals of the presentation or of the lecture, (d) write the notes in an

organized way with ordered steps, so that they will be clear in later reading, and (e) annotate your notes during class, which will save your time and allow you to follow the instructor.

Abbreviations can help students to annotate their notes especially in the subject of mathematics.

Annotations help students to follow the instructor and allow their notes and the instructor's voice to happen simultaneously. Examples of abbreviations in mathematics class can be shown in the following Table 1.1.

Table 1.1 Examples of Abbreviations in Math Class

Spoken Words	Abbreviations
If and only if	iff
Theorem	Thm
Proposition	Prop
X is an element of real numbers	$X \in \mathbb{R}$

Abbreviations can improve students' speed in writing notes as compared with writing verbatim what the instructor says. One study has found that students who used strategic note-taking recorded 53% of the cued lecture points from the lecture, but students who used conventional note-taking recorded only 39% of them (Boyle, 2011). Not knowing the strategies of note-taking produces poor notes. Catching the keywords of the lecture means that students are able to identify the main concepts in the topic. I think students at the university level of education are familiar with taking notes and will not have much difficulty in identifying keywords.

Technology for Note-taking

There are a lot of devices that students can take notes with, such as iPad, Tablet PC, a smart pen, and even a smart phone. If a student wants to take notes using one of these devices, what are the negative or positive effects that technology might cause in the notes? Does the technology affect their strategies of note-taking, or the student's habits in writing notes?

Although we have many different devices and each of them might have a unique functions, their cost can be a problem for some students. The traditional way to take notes, with paper and pen, is a familiar way to take notes. Students prefer this way not only because it is easy for them but also because of the inexpensive cost. Some students find it difficult to change their style, especially if they have used it for many years. They see traditional note-taking with pen and paper as faster and more comfortable. Because of the low cost and familiarity of paper, technology might not completely replace the traditional style of taking notes in classrooms. Before going through the recent studies in using the technology in note-taking I would like to give simple descriptions of the two devices used in the experiment. The first device was a "smart pen".

What is a Smart Pen and How Does it work in Note-taking

A smart pen is a pen that can produce an audio recording of everything in the lecture with crisp, clear sound. It is larger than a regular pen. The ink cartridge is replaceable. It has an OLED display to show the time that spent in recording and the remaining storage capacity. "Smart pen saves your notes and recordings to your computer for fast, easy access to what is important" (Livescribe, 2012). Students can share their notes by sending them through email. Additionally, the smart pen can convert handwritten notes into digital text after they are downloaded into a computer. The smart pen can play back movies of the notes as they are written out along with the

recorded audio. It comes with a special notebook with papers that have very small dots in the background in a machine-readable pattern. This special notebook enables students to record when they wrote a word or a sentence so they can play back the recorded audio of the instructor's explanation at the moment that they wrote that word just by tapping on it (See Figure 1.1).

Figure 1.1 The Smart Pen Design



“Smart Notes Assistance Program, A Learning Mode” is an article from the American Society of Engineering Education (ASEE), by Neil Schiller, who tested the efficacy of using a searchable digital notebook with providing students supplemental help. The supplemental help is written information with verbal explanations with the instructor's voice recorded. The study was conducted in an introductory college physics course. He developed 91 pages of supplemental help for the PHYS-171 course. The result of this study is 87% (n=8) of the students who used the program mentioned that the program helped them in learning the material and they recommended it to all students. The program helped 25% of students in raising their grades (Schiller, 2011).

William M. Ferriter, in “A Pen That Remembers,” describes several advantages of *Livescribe pens*, a type of smart pen. One advantage is that students with poor or incomplete notes can access a recording of the teacher’s lecture that was occurring at the time they were taking those notes. In this way, the smart pen can help them complete their assignment. Ferriter suggests to teachers that students use that pen in their classes since it does a great job of sharing the notes through internet access. “Livescribe pens are worth exploring because they put affordable digital tools directly into the hands of students. That should be the primary goal of any educator working to redefine teaching and learning in the 21st century (Ferriter, 2011).” While Ferriter theorizes that a smart pen aids note-taking, no studies are cited, so we need to test whether it actually helps, particularly for technical classes.

What is the iPad and How Does it work in Note-taking

The second device we had in the experiment was the *iPad*. It has a lot of apps in many different subjects such as: science, art, history, music, etc. It also has a lot of note-taking apps in both free and paid versions. Students can take notes with the iPad with a special pen called a stylus or by typing the notes (See Figure 1.2).

Figure 1.2 Typing or Writing on an iPad



Today, iPad is increasingly popular with people. On April 3, 2010, Apple introduced the first iPad version and the company sold one million in only 28 days (Apple, 2010). About two years later, the most recent version of the iPad was launched on March 16, 2012 and Apple sold three million in only four days (Apple, 2012). In my literature search, I found no studies involving students using an iPad to take notes, however, the iPad has been used in education for many purposes. In the field of physical education, Oleg Sinelnikov experimented with using the iPad during the volleyball season. In this study, students in grades 7-8 were provided an iPad that had a library of video task cards. These videos were short descriptions of some exercises, for example a warm-up. The videos were created by a teacher or were from YouTube, so students had a chance to watch the videos before the game of volleyball started. “The use of the iPad added a degree of seriousness and professionalism to the entire season,” (Sinelnikov, 2012).

The iPad also can be helpful for special needs students. “Students with Down syndrome, autism, and hearing disabilities are taking to iPads and other tablet computers in a big way to use an application called Proloquo2Go. The students are able to scroll through pictures or choose phrases and sentences on the touch-screen that the computer speaks for them” (Shah, 2011)

Research Questions

In this study, four students were provided an iPad or a smart pen for one week. The investigator in this study sought to answer the following questions regarding the effects of technology in note-taking:

- What changes does technology make in note-taking?
- Would taking notes by technology change student habits of note-taking, including the strategy of taking notes, and the amount of their notes?

- Would providing students with a standard note set along with a note-taking tool (such as the iPad) improve student focus on important details, since it is more difficult to write with the stylus so they can only write the important details?
- Would providing students with modern technologies (such as a smart pen which provides an automatic audio recording) allow students to choose where to focus their attention?

Chapter 2 - Methodology

The study was conducted at Kansas State University. Participants were taken from Math 730, “Abstract Algebra,” a graduate class that may also be taken for undergraduate credit. Of eight students who were enrolled in fall semester, six students participated in the experiment. Four participants were graduate students and two were undergraduate students.

The Environment

The class met three times per week with a professor. The 50-minute class was spent with the instructor explaining new concepts, theorems, proofs of these theorems, and examples. The instructor sometimes gave students a handout as a practice exercise or as partial notes on a certain proof. The study was conducted at the end of fall semester with only five lectures left. Five students were given the option of choosing their preference of either an iPad or a smart pen to take notes. As a result, three graduate students chose an iPad, and two students chose a smart pen. One of the smart pen users was a graduate student and the other one was an undergraduate student. An undergraduate student was chosen to use traditional note-taking with pencil and paper. The traditional note-taker was a female student and she was chosen because of her clear handwriting since her notes would be posted. Students who participated in this experiment were free to choose any app they liked, whether free or not, with the researcher paying the cost. Also, students had the chance to use the device in their other classes. The first lecture was the last class before the Thanksgiving Break. Students were given an opportunity to adjust to the devices during the break week. After the break there were four lectures left.

Students were provided a good set of notes taken by the student who took notes by paper and pen, in the traditional style. These notes were posted to the students immediately after each class, so they would not miss any details, especially for those who could not write good notes since they were adjusting to a new technology. At the end of the experiment, the devices were collected and were made copies of the students' notes for all five lectures. The student who was chosen to take regular notes with pencil and paper copied whatever was on the blackboard without adding any words or ideas and without skipping any details. This student was named "student P&P" referring to pencil and paper. After five lectures of note-taking, the five students who used devices were interviewed to ask them several questions about the experiment. The questions were based on their point of view of having a smart pen or an iPad as a tool for note-taking in their classes.

Interview Questions

- 1) Which technology did you use for note-taking?
- 2) Why did you choose this device?
- 3) What did you expect to be different with using this technology?
- 4) What differences did you find in using this technology?
- 5) What things did it make easier?
- 6) What things did it make harder?
- 7) How long did it take to adjust to the technology?
- 8) How do you use your notes for studying?
- 9) Did your studying change when your note-taking changed?
- 10) Did you use the posted notes we made available?
- 11) Did you like using the technology?

- 12) What changes would you like to see to improve the technology?
- 13) Do you recommend students to use technology in note-taking?
- 14) Are there any other comments you would like to make?

The Layout

Analyzing the students' notes depends on analyzing student P&P's notes. After the students' notes were collected, they were coded by counting how many times occurrences in different categories happened. I organized the codes into two different categories of general and mathematical codes.

General Codes

General codes measured the basic strategies of note-taking. In order to know the effects of technology on the strategies of note-taking, I identified the following items:

1) The number of statements:

The number of statements can be counted by listing the steps of the lecture. For example, the professor started a lecture by recalling the important concepts that were in the previous lecture, so this was named statement 1. The next statement was the goal of the new lecture, as the professor mentioned it, and wrote it in the black board as well. Definitions, propositions, corollaries, observations, theorems, proofs, examples, and headings were each considered to be a statement.

2) The number of keywords.

Keywords can be defined as the code of the lecture, or the significant words that help students understand the topic of the lecture. An example of identifying the keyword from the lectures is:

Proposition: A polynomial of degree two or three over a field F is irreducible if and only if it has no root in F .

The keyword: irreducible polynomial.

3) The number of main ideas:

Main ideas are the basic and essential information in the lecture that help students understand the main goal in the lecture. New concepts play an important role to identify the main idea in the lecture, for example:

Corollary: (Eisenstein's Criterion for $\mathbb{Z}[x]$) Let p be a prime in \mathbb{Z} and let

$$f(x) = a_n x^n + a_{n-1} x^{n-1} + \dots + a_1 x + a_0 \in \mathbb{Z}[x], n \geq 1. \text{ Suppose } p \text{ divides } a_i$$

for all $i \in \{0, 1, \dots, n-1\}$ but p does not divide a_n and p^2 does not divide a_0 .

Then $f(x)$ is irreducible in both $\mathbb{Z}[x]$ and $\mathbb{Q}[x]$.

- **Main idea:** how to determine whether a polynomial is reducible or not by using the Eisenstein's Criterion method.
- p does not divide a_n and p^2 does not divide a_0 cannot be a main idea in this statement.

4) The number of students' ideas:

Technology might affect students' habits in note-taking by making it easier or harder for them to add their own ideas that were not written on the black board. Students who used to write more details in the notes might find it difficult to add to their notes since the pen in traditional note-taking had changed to a stylus on the iPad. Additionally, students who used the smart pen might write down fewer ideas in general because of the recording feature, so technology might

play a role in changing the student's way of note-taking. On the other hand, students might write more of their own ideas because the pen has already recorded the instructor's ideas.

5) *The page length of notes for each lecture:*

Although the length of each lecture was 50 minutes, the length of the notes might be affected by the technology. Students might make their notes shorter or longer than the length of student P&P' notes. Also, we might find a big difference in the length of notes when we compare students' notes before and after using the technology.

6) *The numbers of pictures (doodles):*

After collecting students' notes, it was noted that one student had doodling in his notes as many as 15 doodles in each lecture. I counted the number of doodles in each lecture incase this might change due to the change in note-taking style.

Mathematical Codes

Students' notes can be analyzed by identifying some items that are specific to Mathematics, the field of the class which was selected for the experiment. Since Mathematical lectures have a large number of equations, symbols, examples, theorems, proofs, and diagrams, I must identify the following items:

1) *The number of justifications:*

Justification is a mathematical acceptable reason for doing something. The number of justifications can be considered as the number of proofs and the number of examples in the whole lecture. Using technology in note-taking might affect student's style of writing down all

the examples and the proofs that were in the lecture. A student might think it helpful to write down only one example and listen to the rest of the examples by using the recording feature.

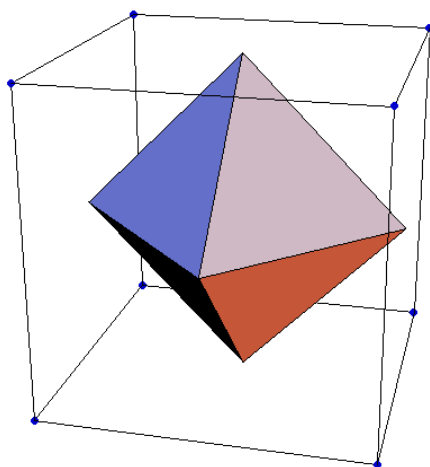
2) *The number of theorems:*

Theorems are significant statements in Mathematics classes, and each lecture included at least one. Counting the number of these theorems that students actually wrote down might identify a difference between their notes and student P&P notes. These differences in the numbers might come from using technology in note-taking.

3) *The correctness of diagrams:*

The old saying “one picture is worth a thousand words” catches an essential idea. In the field of Mathematics, diagrams play an important role in visual literacy and better understanding by clarifying ideas. In the experiment, there was only one diagram in all five lectures and that was probably because Abstract Algebra does not traditionally have a lot of diagrams. Notes were examined to see if students reproduced that diagram in their notes or they reproduced a different diagram. That unique example of diagram was” The octahedral group which is isomorphic to the symmetric group S_4 ”:

Figure 2.1 The Unique Diagram in the Notes



4) The number of abbreviations:

Abbreviations that relate to mathematical language are used a lot in mathematics classes, especially when I am talking about the task of note-taking. Students might want to save time by using abbreviations in their notes even if the professor did not write those abbreviations on the board. The count of the number of these abbreviations might be different from student to student, from device to device and from old notes to new notes for a certain student. An example of an abbreviation is:

Statement: *Let F be a field and let $p(x)$ be a polynomial in the polynomial ring $F[x]$.*

Then $p(x)$ has a factor of degree one if and only if $p(x)$ has a root in F , i.e., there is an $\alpha \in F$ with $p(\alpha) = 0$.

Abbreviation: *let F -field and $p(x) \in F[x]$, then $p(x)$ has a factor of deg 1 $\Leftrightarrow \exists \alpha \in F$ s.t $p(\alpha) = 0$.*

Additional Analysis

1) Comparing the coding of the old notes and the coding of the new notes

In addition to comparing the students' notes to student P&P's notes, another analysis was to compare students' notes before and after using technology in note-taking. That happened by coding the old notes for each student. Five lectures of students' old notes were looked at since there were five lectures in the experiment. After this coding, results that from the old notes and results from the new notes were compared to their corresponding P&P notes, and the results of those comparisons were compared to identify differences between old and new notes.

2) Comparing the analyses of different styles

A smart pen, the iPad, and the traditional notes were different tools for note-taking. Each of them might produce different analysis with different data. The results of each student compared with the results of single student P&P's analysis. Studying this comparison might give a result of how students acted with the devices in the task of note-taking.

3) Comparing the analyses of different classes for a certain student:

Since some of the students took notes for their other classes using the devices that they had, the uses of the record feature in different classes were counted. To find out know how many times students used the record feature in different classes with different professors. Taking notes by iPad, smart pen, or even the traditional way might be affected by professors. Professors are different either in their voices or in the way of their representations. Using the smart pen in classes with a fast speaker might help students to catch the details by recording the lecture, so different classes with different professors might give different effects of technology. Since one student used his device in different classes, that student's notes in his Topology class were compared with his notes in the Algebra class.

Limitations

This study was conducted in a small class, with only six participants in the experiment. In order to have a more generalizable result, we would need to have more participants in the experiment. Also, it is better to have students who are already used to taking notes in the lecture. One student preferred to only listen to the lecture without take any notes. This affected the results since he did not have old notes to compare. In addition, for various reasons two students

did not complete notes for all five lectures. Furthermore, five lectures for this experiment was not enough time. If the experiment were longer, the students would have had more time to become accustomed to their technology, and the results would better reflect how a competent user would take notes.

Chapter 3 - Results

In this chapter I am going to go over the results of the analysis in two parts. The first part is the results of content analysis found by looking at all the codes that were mentioned in chapter 2. The second part is the results of the interviews with the questions that were mentioned in chapter 2 and analysis of how the interviews explain what happened in the results of students' notes. The conclusions that I drew from these results will be discussed in the next chapter.

Before I analyzed students' notes, I wanted to name each student and identify the level of study. Additionally, Table 3.1 shows which device each student used in the experiment, how many sets of new and old notes were analyzed and how many students were interviewed.

Table 3.1 Student Information

Student	Graduate/ Undergraduate	The Device	# of New Notes Sets	# of Old Notes Sets	Interviewed
Student 1	Grad	Smart Pen	5	5	Yes
Student 2	UnGrad	Smart Pen	5	5	Yes
Student 3	Grad	iPad	5	5	Yes
Student 4	Grad	iPad	4	0	Yes
Student 5	Grad	iPad	2	5	Yes
Student P&P	UnGrad	Traditional	5	5	No

In Table 3.1, student 4 had only four sets of new notes that I analyzed because he missed one lecture during the experiment. This student had no old notes because he did not take any

notes before the experiment. Student 5 missed the class three times during the experiment, so he had only two sets of new notes.

Analysis of the Notes

General Analysis

The general coding for students' notes leads to consideration of the basic effects of technology on the strategies of note-taking. After coding each student's notes and comparing the code counts for each student to student P&P, the comparison of number of statements present in the notes gives a measure of the percent of missing details in each lecture. Table 3.2 shows the number of statements for each student.

Table 3.2 The Number of Statements

	Smart Pen Users		iPad Users			Traditional Notes
Lecture	Student 1	Student 2	Student 3	Student 4	Student 5	Student P&P
1	5	5	9	4	No Notes	9
2	12	15	15	7	12	15
3	3	5	3	1	No Notes	5
4	11	15	14	No Notes	8	15
5	15	16	14	4	No Notes	16
Total	46 \simeq 77%	56 \simeq 93%	55 \simeq 92%	16 \simeq 34%	20 \simeq 67 %	60

Comparing to the number of statements in student P&P' notes, student 1 had 77% of statements in his notes, while student 2 had more statements (93%) than student 1 in his notes but still less than 100%. The iPad users presented a challenge. Student 3 had 92% statements in

his notes, but student 4 had only about a third of the statements for the four lectures that he attended. On the other hand, even though student 5 had only two sets of notes, he got about two-thirds of the statements in lecture 2 and lecture 4 (See Table 3.2).

The ability to identify the keywords was affected by technology. Table 3.3 shows the results by counting the number of keywords in each student's notes for each lecture.

Table 3.3 The Number of Keywords in the Notes

	Smart Pen Users		iPad Users			Traditional Notes
Lecture	Student 1	Student 2	Student 3	Student 4	Student 5	Student P& P
1	6	6	7	5	No Notes	7
2	13	13	13	10	13	13
3	6	7	6	1	No Notes	8
4	11	11	11	No Notes	9	11
5	9	9	8	4	No Notes	9
Total	45 \approx 94%	46 \approx 96%	45 \approx 94%	20 \approx 54%	22 \approx 92%	48

As you can see in Table 3.3 there is not a large difference in the numbers between the smart pen note-takers and the traditional note-taker. Student 3, who used the iPad to take notes, had 94% of keywords in his notes. Student 4 had only 54% of keywords for four lectures. On the other hand, student 5 had 92% of the keywords for two lectures.

Identifying the main ideas is another basic factor in well taken notes. Counting the numbers of these main ideas in each student's notes for each lecture for each student helped me to quantify how different technologies affected whether student notes captured key concepts from lecture. Table 3.4 shows the number of main ideas that were in students' notes.

Table 3.4 The Number of Main Ideas in the Notes

	Smart Pen Users		iPad Users			Traditional Notes
Lecture	Student 1	Student 2	Student 3	Student 4	Student 5	Student P&P
1	4	4	5	3	No Notes	5
2	8	8	8	4	7	8
3	2	4	3	1	No Notes	5
4	8	9	8	No Notes	6	9
5	6	6	6	1	No Notes	6
Total	28 \simeq 85%	31 \simeq 94%	30 \simeq 91%	9 \simeq 37%	13 \simeq 76%	33

Each student had different results. For the smart pen users, student 1 recorded 85% of the main ideas in his notes, while student 2 recorded 94% of the main ideas in his notes. For the iPad users, student 3 recorded 91% of the main ideas in his notes. Even though student 5 had fewer sets of notes than student 4, he had a greater percentage of the main ideas than student 4 (See Table 3.4).

Adding students' own ideas in the notes is an important factor in note-taking that is affected by technology. Because the traditional note-taker, student P&P, wrote whatever was on the board, without adding or leaving out any words, no student ideas were recorded in these notes by the conditions of the experiment. Table 3.5 shows the number of students' ideas in each lecture for each student.

Table 3.5 The Number of Student Ideas

	Smart Pen Users		iPad Users			Traditional Notes
Lecture	Student 1	Student 2	Student 3	Student 4	Student 5	Student P& P
1	4	4	0	0	No Notes	0
2	4	2	0	0	0	0
3	0	1	0	0	No Notes	0
4	1	1	0	No Notes	0	0
5	4	3	0	0	No Notes	0
Total	13	11	0	0	0	0

Both smart pen users did include their own ideas, but none of the iPad users did so. For those who used the smart pen, the numbers vary from one lecture to another while the numbers are constant, zero, for those who used the iPad and the traditional style (See Table 3.5).

Table 3.6 shows the length of each student's notes and for all five lectures.

Table 3.6 The Length of Notes for Each Lecture

	Smart Pen Users		iPad Users			Traditional Notes
Lecture	Student 1	Student 2	Student 3	Student 4	Student 5	Student P& P
1	1	2	2	2	No Notes	3
2	3	3	11	2	4	5
3	1.5	1	2	0.5	No Notes	1.5
4	2	3	8	No Notes	4	3
5	3	4	8	2	No Notes	3
Total	10.5	13	31	6.5	8	17.5

The length of notes in each lecture varied from 3 to 5 pages in student P&P notes. Since the smart pen has the same size notebook as a regular notebook, the length of notes was similar to the length of the traditional notes. In contrast, the iPad users wrote plenty of pages of notes. However, less information was included on each page by the iPad users, which may have been a result of how the iPad recorded handwriting. Figure 3.2 shows one page of student P&P' notes that taken from lecture 2. Figure 3.1 shows the same page that taken from student 2' notes, who used the smart pen to take notes. He had the same information that written in Figure 3.1. Figure 3.3 shows the same page that taken from student 3' notes who used the iPad to take notes. This page of iPad notes doesn't have even half of the information that was written in Figure 3.1.

Figure 3.2 The First Page from Student P&P' Notes that Taken from Lecture 2

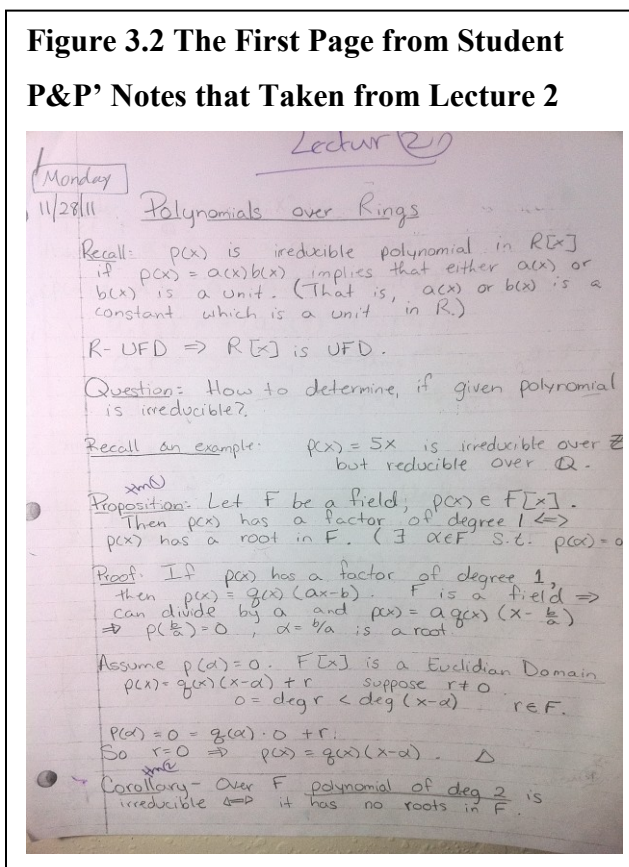


Figure 3.1 The First Page from Student 2' Notes that Taken from Lecture 2

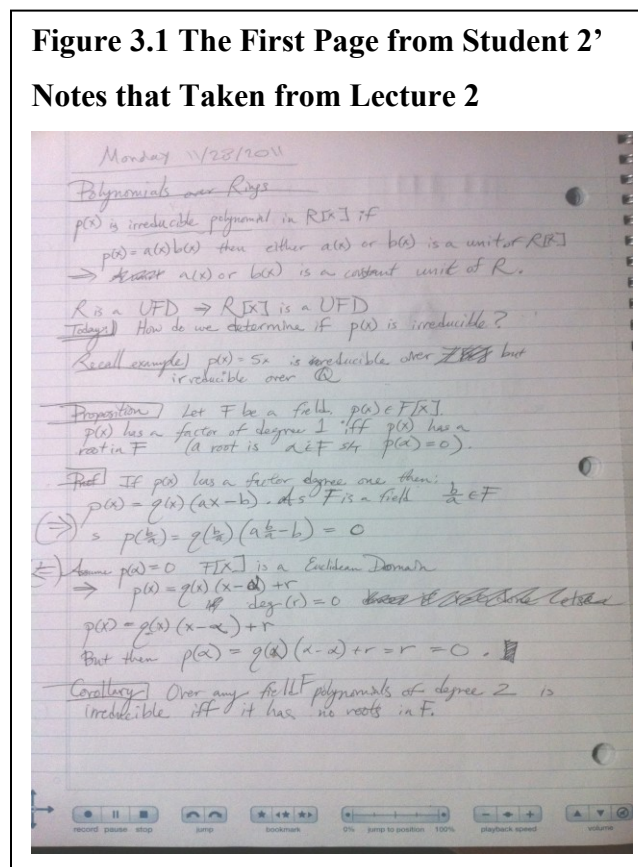
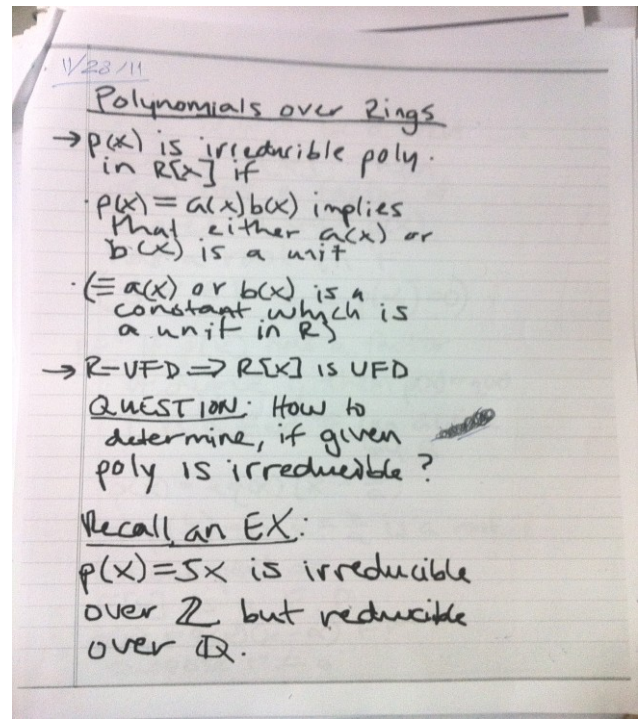


Figure 3.3 The First Page from Student 3'

Notes that Taken from Lecture 2



Mathematical Analysis

The mathematical analysis of the students' notes was dependent on counting the number of justifications, theorems, diagrams, and abbreviations. The results indicated that smart pen users produced similar results to regular note-taking with pencil and paper in recording examples. Table 3.7 shows the number of recorded examples in each student's notes. Student 1 who used a smart pen in note-taking recorded all the examples that were in student P&P's notes. Student 2 who also used a smart pen in note-taking had 92% of the examples in his notes. The iPad users had different results as the results of the previous codes. Student 3 recorded all the examples that were in student P&P's notes. In contrast, student 4 and student 5 had noticeably fewer examples (See Table 3.7).

Table 3.7 The Number of Justifications (Examples)

	Smart Pen Users		iPad Users			Traditional Notes
Lecture	Student 1	Student 2	Student 3	Student 4	Student 5	Student P&P
1	1	1	1	1	No Notes	1
2	6	6	6	1	3	6
3	2	1	2	1	No Notes	2
4	1	1	1	No Notes	0	1
5	3	3	3	1	No Notes	3
Total	13≈100%	12≈ 92%	13≈100%	4≈ 33%	3≈ 43%	13

Since proof is a justification for a theorem, Table 3.8 shows the number of proofs that recorded in student's notes.

Table 3.8 The Number of Justifications (Proofs)

	Smart Pen Users		iPad Users			Traditional Notes
Lecture	Student 1	Student 2	Student 3	Student 4	Student 5	Student P&P
1	0	1	1	0	No Notes	1
2	0	3	3	1	1	3
3	1	1	1	0	No Notes	1
4	0	3	3	No Notes	1	3
5	2	2	2	0	No Notes	2
Total	3≈ 30%	10≈100%	10≈100%	1≈ 14%	2≈ 33%	10

In Table 3.8, student 1 did not record even half of the proofs that were in student P&P's notes. Student 2 and student 3 had all the proofs in their notes. Student 4 had only 14% of proofs in his four lectures' notes. Student 5 had 33% of proofs in his notes four two lectures' notes.

Theorems are considered to be the most basic information in the notes especially in mathematics classes. The corollaries, lemmas, and propositions were counted as theorems since all of them have proofs that follow them. Table 3.9 shows the number of theorems in each class and how many theorems were written in each student's notes with different note-taking styles.

Table 3.9 The Number of Theorems

	Smart Pen Users		iPad Users			Traditional Notes
Lecture	Student 1	Student 2	Student 3	Student 4	Student 5	Student P& P
1	3	3	3	1	No Notes	3
2	4	4	4	3	3	4
3	1	1	1	1	No Notes	1
4	6	6	5	No Notes	4	6
5	1	1	1	0	No Notes	1
Total	15=100%	15=100%	14≈ 93%	5≈56%	7≈70%	15

According to Table 3.9, the smart pen users did not miss any theorems in all five lectures. For iPad users, student 3 had 93% of theorems in his notes, but student 4 and student 5 had fewer theorems in their notes that taken by iPad.

In all five lectures, there was a total of only one diagram. This diagram was in lecture 1. Table 3.10 shows if students had the right diagram in their notes or not. The smart pen note-takers had that correct diagram in their notes, but the iPad note-takers only student 4 had that correct diagram in his notes. Student 3 did not have that diagram in his notes. Student 5 did not have that diagram since he missed the class which had this diagram. The traditional note-taker

had that diagram in her notes since she did not miss any details in the notes that were written on the black board (See Table 3.10).

Table 3.10 The Correctness of Diagrams

	Smart Pen Users		iPad Users			Traditional Notes
Lecture	Student 1	Student 2	Student 3	Student 4	Student 5	Student P& P
Diagrams	Yes	Yes	No	Yes	No Notes	Yes

Abbreviations are one technique used to help record notes efficiently in general classes and in mathematics classes in particular. Table 3.11 shows the number of abbreviations in each student's notes.

Table 3.11 The Number of Abbreviations

	Smart Pen Users		iPad Users			Traditional Notes
Lecture	Student 1	Student 2	Student 3	Student 4	Student 5	Student P& P
1	0	0	0	0	No Notes	0
2	1	2	0	0	0	0
3	0	1	0	0	No Notes	0
4	0	2	0	No Notes	0	0
5	2	6	0	0	No Notes	0
Total	3	11	0	0	0	0

After looking at the students' notes, only student 1 and student 2 were found who used abbreviations in their notes. These two students both used smart pens. None of the iPad users had any abbreviations in their notes. The traditional note-taker did not use abbreviations as part of her task (See Table 3.11).

Additional Analysis

The additional analysis of students' notes mentioned in chapter 2 helped to better understand the effects of technology on note-taking. First, five lectures of students' notes before they used the technology were coded. I refer to these as the old notes. It was impossible to find a sequence of five lectures that all students had attended. I chose the sequence with the greatest number of old notes. Second, the old notes each student who used technology in note-taking were compared with student P&P's old notes. The old notes of the iPad users and the old notes for student P&P were compared. Also, the coding results between the old notes of the smart pen users and the old notes for student P&P were compared. After analyzing student P&P's old notes, the results can be shown in Table 3.12.

Table 3.12 Analyzing Old Notes for Student P&P

Lecture	Old Notes of Student P&P-Traditional Notes-taker						
1	12	4	9	2	4	2	3.5
2	11	5	7	4	3	2	3.5
3	8	5	3	3	1	3	2
4	7	1	5	1	0	1	3
5	8	5	4	3	4	2	2
Total	46	20	28	13	12	10	14
Type of Analysis	# Statements	# Main Ideas	# Keywords	# Theorems	#Justifications (Examples)	#Justifications (Proofs)	Length

After coding five sets of student P&P's old notes, I looked at the same those five sets of notes in each student notebook. Student 1 had a traditional style, with pencil and paper, old

notes. His new notes were taken by smart pen. The old notes for student 1 were coded and the results can be shown in Table 3.13. Note that student 1 had four sets of old notes.

Table 3.13 Analyzing Old Notes for Student 1

Lecture	Old Notes of Student 1-Smart Pen Notes-taker						
1	10	4	9	1	4	1	4
2	11	5	7	4	3	2	3.5
3	8	5	3	3	0	3	3
4	1	1	3	1	0	0	0.5
5	No Notes	No Notes	No Notes	No Notes	No Notes	No Notes	No Notes
Total	30≈79%	15≈100%	22≈92%	9≈90%	7≈88%	6≈75%	11
Type of Analysis	# Statements	# Main Ideas	# Keywords	# Theorems	#Justifications (Examples)	#Justifications (Proofs)	Length

Student 1 recorded all the main ideas in his old notes. Compared to Student P&P, he recorded 92% and 90% of the keywords and the theorems respectively. He also recorded 79% and 75% of the statements and the proofs respectively. His old notes had 88% of examples that were in student P&P's old notes.

Student 2 had traditional style old notes and the results of the coding of his old notes can be shown in Table 3.14.

Table 3.14 Analyzing Old Notes for Student 2

Lecture	Old Notes of Student 2- Smart Pen Notes-taker						
1	12	4	9	2	3	2	4
2	9	5	7	4	2	2	2
3	8	5	3	3	1	3	3.5
4	7	1	5	1	0	1	4.5
5	8	5	4	3	4	2	2.5
Total	44≈96%	20=100%	28=100%	13=100%	10≈83%	10=100%	16.5
Type of Analysis	# Statements	# Main Ideas	# Keywords	# Theorems	#Justifications (Examples)	#Justifications (Proofs)	Length

Student 2 had notes which include all the main ideas, keywords, theorems, and proofs.

He recorded 96% and 83% of the statements and the examples respectively in his old notes.

Table 3.15 shows the results of student 3 who had traditional style old notes. He was an iPad notes-taker in the experiment. He had four sets of old notes.

Table 3.15 Analyzing Old Notes for Student 3

Lecture	Old Notes of Student iPad Notes-taker						
1	No Notes	No Notes	No Notes	No Notes	No Notes	No Notes	No Notes
2	11	5	7	4	3	2	3.5
3	8	5	3	3	1	3	3
4	7	1	5	1	0	1	3.5
5	8	5	4	3	4	2	2.5
Total	34=100%	16=100%	19=100%	11≈100%	8=100%	8≈100%	12.5
Type of Analysis	# Statements	# Main Ideas	# Keywords	# Theorems	#Justifications (Examples)	#Justifications (Proofs)	Length

Student 3 recorded completely all the content that was in student P&P's old notes (See Table 3.15).

Student 4 who used smart pen to take notes in the experiment did not have old notes. Before the experiment, he was just sitting in the class and listening to the professor without taking any notes during lectures.

Student 5 had old notes that taken by Tablet PC, and new notes that taken by iPad. His old notes were taken either by typing on the Tablet or by writing with its special pen. The five sets of notes that I coded were taken by typing. After coding his old notes, I found the results that can be shown in Table 3.16.

Table 3.16 Analyzing Old Notes for Student 5

Lecture	Old Notes of Student iPad Notes-taker						
1	8	4	8	2	2	1	1.5
2	9	5	7	4	2	1	2
3	5	3	3	1	0	1	2
4	1	1	1	1	0	0	0.25
5	4	2	3	2	3	1	1.5
Total	27≈59%	15≈75%	22≈79%	10≈77%	7≈58%	4≈40%	7.25≈52%
Type of Analysis	# Statements	# Main Ideas	# Keywords	# Theorems	#Justifications (Examples)	#Justifications (Proofs)	Length

Table 3.16 shows that student 5 did not record much of the content that was in student P&P's old notes.

Summary of the Student Experiences

After five lectures of note-taking with the new technology, five students were interviewed to ask them several questions about the experiment. In this section, I will have better understanding of each student’s analysis results by looking at the results of the interviews with the questions that were mentioned in chapter 2 and analysis of how the interviews explain what happened in the results of students’ notes. I will discuss the summary of the students experiences individually.

Student 1 profile

Student 1 was a graduate student who used a smart pen to take notes. He chose smart pen to take notes with because “I thought my hand writing would be too sloppy using my finger or one of those little pens on the iPad” as he said in the interview (See Appendix B). Table 3.17 shows how the technology affected his style in note-taking.

Table 3.17 The Old and the New Notes for Student 1

Old Notes	30≈79%	15≈100%	22≈92%	9≈90%	7≈88%	6≈75%	11
New Notes	46 ≈ 77%	28 ≈ 85%	45 ≈ 94%	15=100%	13≈100%	3≈ 30%	10.5
Type of Analysis	# Statements	# Main Ideas	# Keywords	# Theorems	#Justifications (Examples)	#Justifications (Proofs)	Length

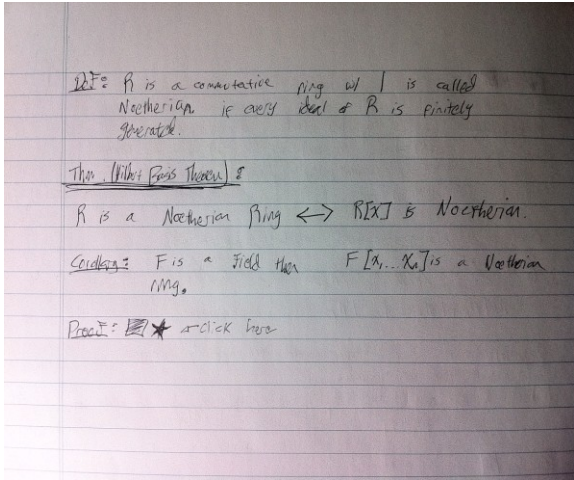
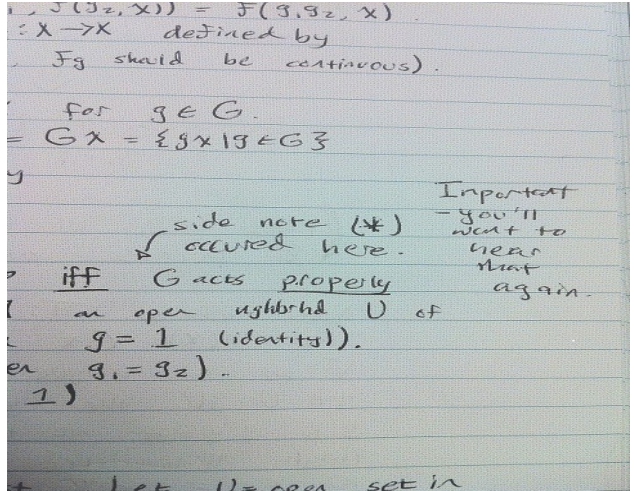
Student 1 recorded better number of some codes such as: keywords, theorems, and examples in his new notes while his old notes had better number of main ideas and proofs. The main change that happened in his new notes was recording proofs. Student 1 wrote a lot of theorems without proofs in his new notes. In the interview he said: “I put less stress on writing

down exactly everything that my instructor said, and also when I got to things that were a little less important like something I don't usually reference anyway, like proofs, when they write out a whole board of proofs, I would usually write a note that said, "proof here," so I would make a little note, and put a little dot where I could touch the pen, then set the pen down and listen to the proof, so that I could then listen to her and pay a little" (See Appendix B).

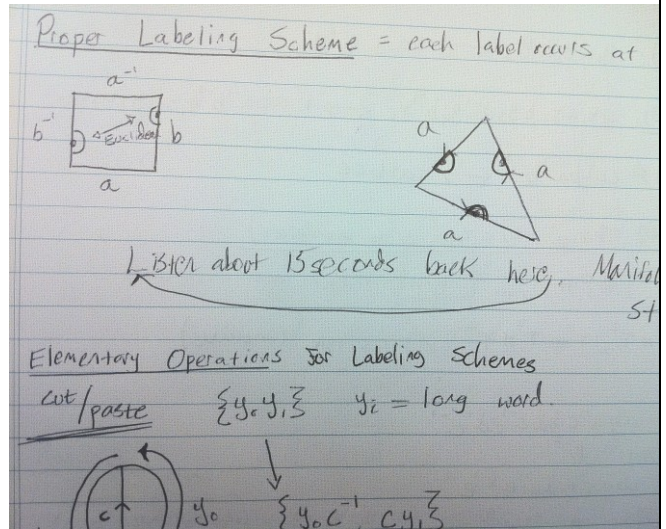
Student 1 used the smart pen in different classes with different professors, but he found that that using the smart pen in Algebra Class was not as helpful as in his Topology Class. In the interview he said: "Easier in Topology, but not a lot easier in Abstract Algebra because Natasha's voice was too quiet for it to be useful for me to listen to notes in Algebra, but Dr. Maginnis projects really well. There should be two sections of notes in there. I did try to use them for Algebra, but, the pen picks up my scribbling really loudly and I also write really hard, I always have, and so you're just hearing scratch, scratch, scratch" (See Appendix B).

Table 3.18 shows examples of using the recording feature in different classes.

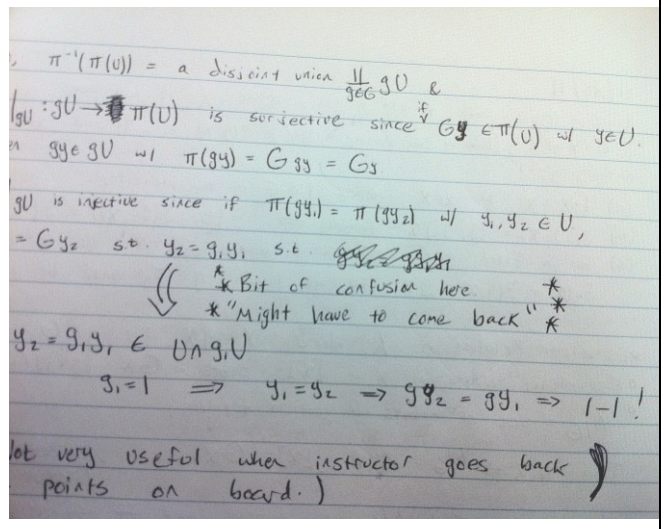
Table 3.18 Examples of Using the Recording Feature in Different Classes

Algebra Class	Topology Class
<p>1)</p> 	<p>1)</p> 

2)



3)



Student 1 adjusted to the device by the first lecture “I think the first day I was already feel in, I mean it’s just like writing with a pen” he said in the interview. Recording the lecture played an important role in doing his assignments. He said: “it became really, really useful in my last Topology assignment. We get to go and talk to him for a while and get help, and one thing I did, was I brought that and as he explained the problem and I wrote down, at each point, he talked so fast that you only can kind of get an idea of what we’re supposed to do there and then the notes

get a little crazy, but having that to listen to, definitely, I don't think I would have completed my Topology assignments as well without it" (See Appendix B).

The two issues for student 1 with the smart pen that it did not have an eraser. As he said in the interview: "Harder in the sense that I couldn't erase, and so several times I had to scribble out stuff". Also picking up the soft voice of one instructor was another issue for him. Using smart pen in note-taking changed student 1's studying because the benefits of the recording feature. He said: "I had that new option of listening to exactly what the professor said, so it changed in the way that, now I no longer had to say, "OK, what did I think they were trying to say when I wrote this, or do I remember exactly what that was, or, change in the sense that I knew exactly they were saying when they said that because now I can go back, click on that and listen to what they said" (See Appendix B). He did not use the posted notes, student P&P's notes, because "I was able to keep up in taking notes. We took about the same notes except for you have the proofs written out, whereas I have the recordings" he said.

Student 2 profile

Student 2 was an undergraduate student who used a smart pen to take notes. He did not find a big difference from the regular note-taking. In the interview he said: "I took notes the same way and so I had the hard copy, so everything that I had earlier, I still had, only now, I also had a sound recording and digital copy, which was nice" (See Appendix B). The adjustment to the device took very little time. Student 2's studying did not change after he changed his device for note-taking. He said: "the device didn't change my study patterns very much, usually because if I want to study, I just do more exercises from the text". He did not use the posted notes,

student P&P's notes, because "I do not need to" he said. Table 3.19 shows how the technology affected his style in note-taking.

Table 3.19 The Old and the New Notes for Student 2

Old Notes	44≈96%	20=100%	28=100%	13=100%	10≈83%	10=100%	16.5
New Notes	56 ≈93%	31≈ 94%	46 ≈ 96%	15=100%	12≈ 92%	10≈100%	13≈74%
Type of Analysis	# Statements	# Main Ideas	# Keywords	# Theorems	#Justifications (Examples)	#Justifications (Proofs)	Length

Student 2 had similar old and new notes in recording theorems and proofs. He had more written examples in his new notes than in his old notes. In general, the smart pen did not change student 2's style in note-taking, so in his new notes he was able to write close numbers of statements, keywords, main ideas to student P&P's new notes. The length of his new notes was shorter to the length of student P&P's new notes. His notes had some of the abbreviations.

After collecting student 2's notes, I noted that he had pictures so called doodles in his notes. I was excited to know technology's effect in changing the number of those doodles by comparing the notes before and after using the technology. I looked at all five sets notes for both old and new notes, and the result can be shown in Table 3.20.

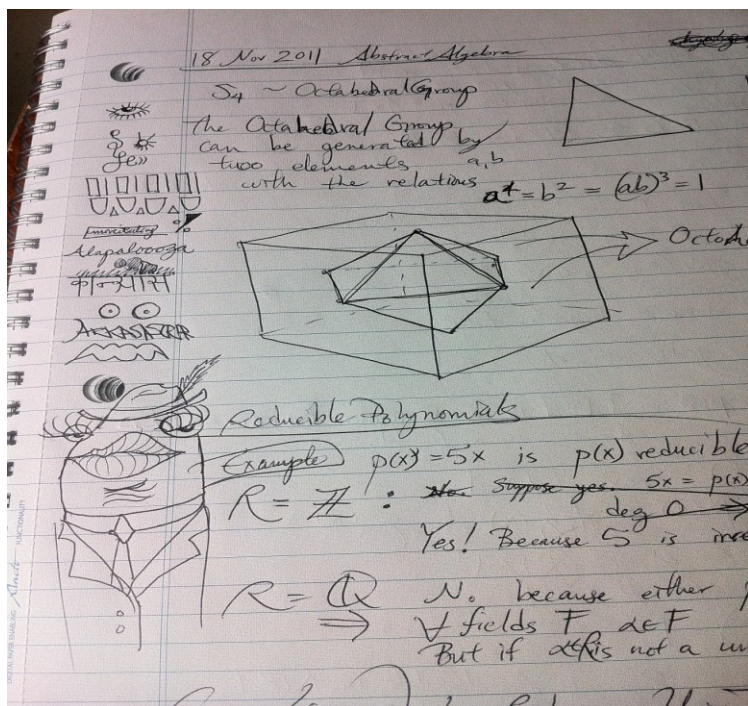
Table 3.20 The Number of Doodles between the Old and the New Notes in Student 2 Notes

Lecture	Old Notes	New Notes
1	8	15
2	9	8
3	0	6
4	7	4
5	4	3
Total	28	36

In Table 3.20, the number of doodles varied in student 2's old notes while the number decreased in his new notes. I was interested to know why the number decreased in his new notes. Also, I was interested to understand why he doodled, what more doodles show, and what no doodles show? Unfortunately, I interviewed students before I analyzed students' notes, so did not have a chance to ask him about drawing, but I had an extra interview with student 2 after I analyzed his notes. He said: "I doodle to keep myself awake during lulls in the lecture if I am tired, to help me to focus on what the instructors are saying, to prevent myself from zoning out completely and missing something critical. No doodles might have meant the lecture was moving faster, or that I was less tired, or that I had another paper to doodle on" (See Appendix B).

The following Figure is an example of student 2's doodles that taken from lecture 1 in the experiment.

Figure 3.4 A Picture of Doodles Taken from Student 2's notes.



Student 3 profile

Student 3 was a graduate student who used an iPad to take notes in the experiment. He chose the iPad in note-taking because he was interesting in using iPad. In the interview he said: “I was actually interested in purchasing an iPad, so I guess it gave me an opportunity to use it. Also, I think it’s a good tool for organizing school work” (See Appendix B). In the first lecture of the experiment he took notes by typing, and then he found that typing notes on iPad was difficult. He said: “it was hard to keep up with the instructor. That was mainly when I was typing, so then I downloaded an app to go ahead and speed up my note taking, which helped, and I was also using the stylus the entire time”. Figure 3.5 shows student 3’s notes that taken by typing on the iPad. It shows mathematical symbols that the student was not able to write down by typing on the iPad. On the other hand, Figure 3.6 shows student P&P’s notes for the same content in figure 3.5.

Figure 3.5 A Picture of Notes Taken by Typing on the iPad

Gauss Lemma:
 R is UFD
 F is field of fractions of R
 $P(x) \in R[x]$. If $p(x)$ is reducible in $F(x)$ then $p(x)$ is reducible in $R[x]$.

Corollary:
 R is UFD, F -field of fractions
Let $p(x) \in R[x]$ and the gcd of all coefficients.
 $P(x)$ is 1.
then $p(x)$ is irreducible in $R[x]$ iff it is irreducible in $F(x)$

theorem: R -UFD iff $R[x]$ is UFD

$R[x]$ is UFD implies R is UFD
(any element in $R[x]$, $p(x) = q_1(x) \dots q_m(x)$
 R - constant polynomials

R is UFD
Let F be the field of fractions
 $P(x) \in R[x]$
 $P(x) = d \cdot p(x)$
 $d \in R$, d has a decomposition into irreducible. (since by assumption R is UFD)

Figure 3.6 A Picture of Notes Taken by the Traditional Style

Gauss lemma: R - is UFD, F is field of fractions of R . $p(x) \in R[x]$.
If $p(x)$ is reducible in $F[x]$ then $p(x)$ is reducible in $R[x]$.

The opposite is not true - (by previous example)

Corollary - R is UFD, F -field of fractions
Let $p(x) \in R[x]$ and the g.c.d. of all coefficients $p(x)$ is 1.
Then $p(x)$ is irreducible in $R[x] \Leftrightarrow$ it is irreducible in $F[x]$.

Theorem R -UFD $\Leftrightarrow R[x]$ is UFD.

R -UFD $\Leftrightarrow R[x]$ is UFD
 $R[x]$ is UFD

Recall: UFD \Rightarrow any element in $R[x]$ can be written as $p(x) = q_1(x) \dots q_m(x)$

Student 3 said “I was pretty good to go and well-adjusted by the third class, for using the technology. So again the first class was typing and then the second class, I switched to writing with a stylus and by the third class, I was continuing with the stylus, but it became easier.” But he also said that he was not able to follow the professor and the delay came from the difficulty of controlling the stylus. Table 3.21 shows student 3’s notes before and after using the technology.

Table 3.21 The Old and the New Notes for Student 3

Old Notes	44≈96%	20=100%	28=100%	12≈92%	12=100%	9≈90%	16.5
New Notes	55 ≈92%	30≈ 91%	45 ≈ 94%	14≈ 93%	13≈100%	3≈ 30%	31
Type of Analysis	# Statements	# Main Ideas	# Keywords	# Theorems	#Justifications (Examples)	#Justifications (Proofs)	Length

The main problem for student 3 is the length of the notes. He had more pages of notes than the pages that student P&P had. He said: “I wanted to start adapting my note-taking in terms of, kind of, shortening the amount of notes that I take and focus on taking down only important things, or stuff that I didn’t know, but it’s very difficult to switch and to adapt and re-style at this point, just because I’m so used to doing, you know, I have my way of note-taking that I’ve been doing for years” (See Appendix B). According to Table 3.21 his notes had most of the statements, keywords, main ideas, theorems, and justifications that were in students P&P notes. His notes did not have his own ideas or any abbreviations (See Table 3.11), and the reason behind that is explained in the interview as: “I’m one of those persons that typically writes down everything that’s put on the board” (See Appendix B). He used the posted notes.

Student 4 profile

Student 4 was a graduate student who used an iPad to take notes in the experiment. This student did not have old notes, so he could not mention in the interview about the differences that he found between notes is taken by iPad and notes is taken by the traditional style. As he stated in the interview he used the posted notes to look at things that were not in the book, and he

adjusted to the device after a couple class period. Table 3.22 shows student 4 results for four sets of notes from the experiment.

Table 3.22 The Old and the New Notes for Student 4

New Notes	34%	37%	54%	56%	33%	14%	6≈45%
Type of Analysis	# Statements	# Main Ideas	# Keywords	# Theorems	#Justifications (Examples)	#Justifications (Proofs)	Length

In Table 3.22, student 4 had poor notes which do not included good number of codes that were in student P&P’s notes. In the interview he said: “since the processing speed of such a device is still pretty low for what it is, I found my note taking to be much more sloppy and more time consuming. Keeping up with my writing, it just kind a estimated; it was not fluent writing so that made it difficult” (See Appendix B). The main problem for student 4 was the stylus design. “try to find some way to get a pen back so you have an actual point to it instead of just like a round ball on the end. I think this one is more of a software thing but have some type of keyboard where you can switch on to the math symbols” he said.

Student 5 profile

Student 5 was a graduate student who used an iPad to take notes in the experiment. This student’s old notes were taken on a tablet PC. From the five lectures in the study, he had only two sets of new notes. He chose an iPad “because I already was used to taking notes electronically.” He found that the iPad was similar to the tablet and adjusted to the device quickly, “within the first, maybe, 20 minutes of using it.” For him, the primary difference between the iPad and his tablet was his ability to write mathematical symbols. The tablet had a

narrow point stylus and a mathematical keyboard that he could use. He found it difficult to type math symbols on an iPad or to write them with the wide stylus. Table 3.23 shows student 5's results for the two sets of notes and five sets of old notes.

Table 3.23 The Old and the New Notes for Student 5

Old Notes	27≈59%	15≈75%	22≈79%	10≈77%	7≈58%	4≈40%	7.25≈52%
New Notes	20 ≈ 67 %	13≈ 76%	22≈ 92%	7≈70%	3≈ 43%	2≈ 33%	8=100%
Type of Analysis	# Statements	# Main Ideas	# Keywords	# Theorems	#Justifications (Examples)	#Justifications (Proofs)	Length

In Table 3.23 the results for both old notes and new notes are similar, except for page length and number of keywords. The difference in length might be because of the change in stylus size from tablet to iPad.

Chapter 4 - Conclusion

In this chapter I will address the research questions that were mentioned in the first chapter. The goal of this study was to assess how technology affects the note-taking process by analyzing students' notes from different angles.

After the comparisons between the old notes and the new notes, the results obtained from the experiment indicate that in most cases, technology did not affect the amount of information in the notes. Student 3's notes were very similar to student P&P. Student 3 took very faithful notes on both paper and iPad, even though he complained of the difficulty of writing on the iPad. Student 5's notes were different from student P&P's, but student 5 was used to taking notes with technology, and the iPad did not change the amount of information in his notes. Both smart pen users had similar information in their notes to student P&P, but they used the smart pen differently. Student 1 used the recording feature of the smart pen to record proofs and did not write proofs in his notes, while student 2 wrote all of the proofs. By recording proofs instead of writing them, student 1 was the only student who changed the amount of information in his notes. Because of the small number of students, and the small number of lectures, I cannot do statistical tests to identify significance.

Although the technology did not affect the amount of information in the students' notes, it did affect the way the students felt about their notes and the way they used their notes. The smart pen helped students to focus on the details of the lecture because it was able to record the lecture to listen to later. Listening to all the details helped students to do well in their assignments. Student 1 did not find all these benefits in Algebra Class, the class that the experiment focused on. He found more benefits in Topology Class with different professor. The reason for these

differences was the professor's voice. He could not hear the Algebra professor when he played back the lecture, so the smart pen became just a regular pen.

According to the interview and the analysis of students' notes I conclude that the stylus affected the length of the notes. The wide end of the stylus changed the length of the notes by making them longer than usual. The students felt that the stylus was not really a replacement for a regular pen, which was much more desirable and easier for them to use. Another conclusion regarding using the iPad in note-taking is it has a disadvantage. As soon as the student's palm touches the screen, it draws scribbles in areas they never intended, so they had to erase these unwanted lines frequently from their notes. This disadvantage made students feel uncomfortable using technology in note-taking since it also wasted their time by erasing those lines.

Discussion

Although e-books have been used by some professors, some of students might have difficulty to study from them. Some students prefer to have a paper textbook in their studying. Similarly, although the number of iPad users is growing every day, most of people might not be able to replace the notebook with the iPad. Even though technology experts try to do their best to improve classrooms and enhance education field, using technology in note-taking depends of students' interest in technology in general.

The students who participated in the experiment wished that there had been a tutorial that would enable them to practice using the iPad or the smart pen in note-taking. Although we gave students a chance to practice with the device that they had during the Thanksgiving break, they did not learn how to use all the faculties the devices have by themselves. As an example, in the

interview one of the participants mentioned that he knew that the smart pen has a calculator, but he did not know how to use it, and as a graduate student he did not have the time to learn by himself. Even though the class was Abstract Algebra which does not have need of a calculator, students used the devices in their other classes which might have some computations that need a calculator. The iPad users did not find an app that provided mathematics symbols, so they did not have an acceptable feeling about their notes. Although students were free to use any app they wanted, they did not find a note-taking app that provided all they needed for taking notes in mathematics class.

Although the technologies in this study did not affect the amount of information in the students' notes, using technology in classrooms can improve student's abilities in understanding the subject and save more time for them if these technologies are designed with student usage in mind. For example, both smart pen users played back portions of lectures to improve their understanding of the material, and to help complete assignments. Getting rid of the scratching sound that appears when writing with a smart pen would give students the opportunity to let the recording feature be more useful. Similarly, I am hoping that one day, a tablet like the iPad can become a replacement for pen and paper by reducing the disadvantages that the students found. Analysis of the results seems to indicate that students' level of comfort and satisfaction in using the iPad and the smart pen vary somewhat. Students desire a technology that they feel comfortable with.

Future Research

I am interested to know if the results would change if I had had different students who had a different major, such as computer science or business. Would technology change the ways

students take notes if those students already had an interest in technology? What about classes for which students do not need to write symbols or draw pictures? Would students find typing notes by using technology in an English class, which has only words an easier task? Also, would the results change if students had at least three weeks of training that trained them how to use the available devices, or if the experiment lasted long and the students had more time to adapt? If there were a tutorial or training before doing the experiment, they might find more benefits of using the technology in note-taking. Additionally, would having a large number of participants and having more than one month of the experiment give more statistically useful results?

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Appendix A - Interview Questions

- 1) Which technology did you use for note-taking?
- 2) Why did you choose this device?
- 3) What did you expect to be different with using this technology?
- 4) What differences did you find in using this technology?
- 5) What things did it make easier?
- 6) What things did it make harder?
- 7) How long did it take to adjust to the technology?
- 8) How do you use your notes for studying?
- 9) Did your studying change when your note-taking changed?
- 10) Did you use the prepared notes we made available?
- 11) Did you like using the technology?
- 12) What changes would you like to see to improve the technology?
- 13) Do you recommend students to use technology in note-taking?
- 14) Are there any other comments you would like to make?

Appendix B - Responses to Questions 1 – 14

Interview 1

- 1) I used the smart pen with that notebook.
- 2) I wanted to try something different from what the other guys are doing and also I thought my hand writing would be too sloppy using my finger or one of those little pens on the iPad, and so I thought it would just be easier for me to continue taking my notes with that, uh, actually, utensil.
- 3) I expected, I didn't explore it as much as I thought I would, but I expected it to do a really good job of picking up the sound. I thought it was going to be a little more advanced than something that I really understand how to use well, and one thing I thought beforehand was that I didn't know how I would do taking notes without an eraser. I thought that could be a problem.
- 4) I definitely, my notes were a little different. I put less stress on writing down exactly everything that my instructor said, and also when I got to things that were a little less important like something I don't usually reference anyway, like proofs, when they write out a whole board of proofs, I would usually write a note that said, "proof here," so I would make a little note, and put a little dot where I could touch the pen, then set the pen down and listen to the proof, so that I could then listen to her and pay a little.
- 5) Easier in Topology, but not a lot easier in Abstract Algebra because Natasha's voice was too quiet for it to be useful for me to listen to notes in Algebra, but Dr. Maginnis projects really well. There should be two sections of notes in there. I did try to use them for Algebra, but,

the pen picks up my scribbling really loudly and I also write really hard, I always have, and so you're just hearing scratch, scratch, scratch. Yes, very (helpful in Maginnis' class), I went back and referenced it multiple times over the homework.

- 6) Harder in the sense that I couldn't erase, and so several times I had to scribble out stuff.
- 7) I think the first day I was already feel in, I mean it's just like writing with a pen. The only difference was when I wanted to make sure that I saw something or heard something that I was gonna want to hear it again, I had to remember that I need to make a note on the side that said "listen here" or "listen 15 seconds back." That's the only difference. The first day, though, it felt good.
- 8) Well, I use the notes whenever I'm gonna review the chapter, but I really mainly use them on homework, and so even before I had the pen and when I had it, that was really the only use I had. I'll probably read over them now, before our final, but during the semester, mainly just for homework. Yeah (I study from my notes usually), I will go through and see, you know, look at the notes over the semester, seeing if I remember everything there, trying to pick out things that are definitely gonna be important for the final, or midterm.
- 9) Yes, only because, I mean, I had that new option of listening to exactly what the professor said, so it changed in the way that, now I no longer had to say, "OK, what did I think they were trying to say when I wrote this, or do I remember exactly what that was, or, change in the sense that I knew exactly they were saying when they said that because now I can go back, click on that and listen to what they said.
- 10) I didn't (use the posted notes) so much, mainly because I was able to keep up in taking notes. We took about the same notes except for you have the proofs written out, whereas I have the

recordings. So, I would imagine if I go back to ever listen to the proofs, then I will use your notes 'cause then I can read along and listen, but that was more out of my laziness, I suppose.

11) Yes. I really liked it for Dr. Maginnis' class. I don't know if I'd continue using it if I was in a class with an instructor who was so quiet, like Natalia. I think I would rather have my pencil and be able to erase, since I probably won't use the listening function of it, anyway. And I didn't actually explore many other functions, so the main use of it to me wasn't very applicable there.

12) I would say it was the ability to pick up the instructor, it was really the only thing, well. I would like some way to be able to erase, if that's possible, and also it would need to be able to pick up the quieter voices. Somehow filter out all the scratching from the pencil. I can't imagine that it would work very well in a really large lecture hall when you have a lot of students around, the noises. I would say that would be one thing. Better sound pick up. But other than that I only once ran into trouble where I put down a point and it kept on taking me back about 10 minutes to a different spot. It must have misread what I was trying to get it to do. But the main problem was the sound. (Did you play back the lecture?) No, I didn't listen to the whole lecture. I would listen to certain parts, if I was ever unclear about what my notes were saying there but I never sat down and said, you know, alright, I'm gonna sit for an hour and listen to the entire lecture and go through the notes.

13) Yes, I think I'm halfway tempted to buy one as long as I continue to have instructors who can project their voices. Like I said it became really, really useful in my last Topology assignment. We get to go and talk to him for a while and get help, and one thing I did, was I brought that and as he explained the problem and I wrote down, at each point, he talked so fast that you only can kind of get an idea of what we're supposed to do there and then the

notes get a little crazy, but having that to listen to, definitely, I don't think I would have completed my Topology assignments as well without it.

14) If I was to purchase one, yeah (I would keep using it). I understand they're, like, \$100 or so, so that's a bit of an investment, so I don't know if I would do that, but I definitely see the benefit of having it. I also, I guess I almost feel if it wasn't for the fact that you can point to where in the notes, I would almost do a recorder as well, just like what you are using there. I could see that being very useful. But being able to pick out a specific spot that was important to you would be nice as well. (Do you have any other comments?) I guess if we were to do it again, I'd like to get a little more, do a little more of a tutorial on how to use it and maybe I could get more use out of it, rather than just the recordings. I understand that it has, like, a calculator and some other stuff. I imagine there is more to it as well, but I think if you were to do it again, and I was sitting in on it, to sit down with either you or Dr. Bennett and you, know, go through all the functions and maybe have a little booklet that says a little more, maybe I would have got more use out of it, maybe, and want to buy it more, even.

Interview 2

- 1) The Smart Pen.
- 2) I think they decided to use it.
- 3) I've never used one before, or seen it, so I didn't have a lot of expectations. You can make, like, a digital copy of your notes.
- 4) As opposed to just regular note-taking? It was, I took notes the same way and so I had the hard copy, so everything that I had earlier, I still had, only now, I also had a sound recording and digital copy, which was nice.

- 5) To take notes? The same, because, I mean, I'm just writing with a pen, [unintelligible]. (So there is no big difference.) No, nothing. I mean, I think one time, the battery ran out on the pen in lecture, but then there was just taking notes on paper.
- 6) Nothing.
- 7) Very little time.
- 8) I don't consult them very often. Usually, for me, it's more, I write it down and that helps me remember it and then if I need to look something up, usually I consult the text and don't consult the notebook.
- 9) It (the device) didn't change my study patterns very much. Um, usually because if I want to study, I just do more exercises from the text.
- 10) No, I don't need to.
- 11) Yeah, yeah, it has lots of interesting little functions that I didn't have enough time to, like, really learn and play with. I know you can do things, like it has a calculator and a translator. I don't know how much of that would be super useful for math, but I mean, it's nice to have the recorded lecture, I like that. It was, I did really like having the recording and I looked at that, one of her recordings, one time, and that was kind of nice. I played back just a little bit of it (one of her lectures). It wasn't a question part so much as it, ah, an interest, I guess. It was when she was talking about the octrahedral [unintelligible].
- 12) I don't know, ah, um, I mean, I can't think of anything. Mmmmm. I mean, the only problem I had with it was that the battery ran out one time, but that's just 'cause I didn't charge it. I don't know what I would do to improve it. I always take notes in pen, so I don't want to erase, you know. That wasn't a problem for me.

13) Sure. I think it would be, it's actually, if you're somebody who uses your notes a lot, I think it would be really helpful to go back and, because you have the recording and you have it synced up with your notes, if your notes aren't very clear, hopefully you can [unintelligible]. (Are you going to keep using this device, if you have one?) Yeah, yeah, because I know there have been times in the past where I did check my notes on something and it wasn't very clear, so maybe that's why I don't check my notes that often, 'cause it's not complete enough, so maybe the pen would help me.

14) Not that I can think of.

An Extra Interview with Student 2 after I Looked at his Notes

Researcher: Why did you draw doodles in your notes? Is doodles are important to you, Why? and What does more doodles show?

Student 2: I typically doodle during class anytime I am not writing something down. Sometimes the doodles are related to what the professor is saying, sometimes not, but it helps me to focus on what they are saying rather than think about something unrelated. If I am especially tired I doodle to keep myself awake during lulls in the lecture. I imagine the number of doodles is around the time doodling, and that is probably close to the amount of time where I don't feel whatever is happening in the lecture is that critical (or at least not worth writing), but I want to prevent myself from zoning out completely and missing something critical. Maybe the professor is working a HW problem I have finished or reviewing her notes, something like that. No doodles might have meant the lecture was moving faster, or that I was less tired, or that I had another paper to doodle on.

Interview 3

- 1) The iPad.
- 2) Well, I was actually interested in purchasing an iPad, so I guess it gave me an opportunity to [unintelligible] up on, but, you know and I obviously have several interests in using an iPad, considering that I wanted to purchase it. I think it's a good tool for organizing school work. The apps are great. There is plenty of them out there that we can use for math and you can also take notes on it.
- 3) Well, I guess when you guys had first shown them to us, I had noticed that it was probably going to be a little difficult, but, and that's in terms of being able to keep up, you know, both if you're going to type or hand-write using an app on the iPad, but I was able to adjust a little bit, so it became easier, but even if I were to have my own iPad, I think that I would continue to take hand-notes, just 'cause that's what I prefer.
- 4) Well, let's see, like I said, especially at first, it was hard to keep up with the instructor. That was mainly when I was typing, so then I downloaded an app to go ahead and speed up my note taking, which helped, um and I was also using the stylus the entire time, but the processor in here is kind like a little delayed with writing, but it's not as much of a factor that really negatively affects note taking on it, I would say, but there are a couple things, you know, I guess your page that you are taking notes on is kind a shrunk a little bit. You can go ahead and expand it, but you're constantly having to move and adjust while you are writing, which is just extra time and extra things to be concerned about. So, doing that stuff while note taking, sometimes the machine will, or the iPad itself will kinda act up a little bit, and so it's a little temperamental, so it gets frustrating.

- 5) Well, it can be organized a lot better. I think you could access it a lot quicker. I guess, you know, instead of having to flip through a ton of pages, it's all right there, in e-format, so that would be one perk. I guess that's the major feature, probably, the organization. In terms of doing things with your notes, you can go ahead and then, I think it could be possible to, like, for instance, take any articles or anything like that that you may have for research and you can import PDFs into another file and start writing on those, so that'd be a feature you may be able to slip things in between your note set that you might take in class, and it's also possible to email things like that if we can get it working.
- 6) Explained in question 4.
- 7) Well, in terms of using it in the classroom, I would say I was pretty good to go and well-adjusted by the third class, for using the technology. So again the first class was typing and then the second class, I switched to writing with a stylus and by the third class, I was continuing with the stylus, but it became easier.
- 8) My notes usually play a pretty big factor in studying for exams and completing homework. I'm one of those persons that typically writes down everything that's put on the board, so especially when studying for exams, I go back and I make another copy of the important definitions or theorems, things like that, but, you know, I would definitely re-read through notes, aside from the text, too, while preparing and it's always nice to have everything written down from class, because if there's a homework problem, for instance, that we may have covered in class then I have access to that.
- 9) I wanted to start adapting my note-taking in terms of, kind of, shortening the amount of notes that I take and focus on taking down only important things, or stuff that I didn't know, but it's very difficult to switch and to adapt and re-style at this point, just because

I'm so used to doing, you know, I have my way of note-taking that I've been doing for years, so it would, it almost inspired me to try to adapt to a new method, but it's harder than it sounds.

10) Yes, I did.

11) Yeah, yeah, I really enjoyed it, over all.

- What apps did you use for note-taking?

- Oh, yeah, the first one, for day one, when I was typing was just the notes application, which comes with the iPad. And then I installed just a notes app, I think it's just titled, "Notes." It says, let's see, "Notes," maybe by Paper Corp [?] and it was a free app.

12) They could probably put some work into, I guess, the response of using the stylus on the tablet and still, I guess, make improvements in terms of while taking notes, make it more user friendly. It's pretty straight-forward, but there are still a couple almost bugs, I'd say, like when we're writing, you know, for instance, you go to, in math, right, you have like, dot, dot, dot, you make three dots and you don't do it very precisely, the tablet takes it as like, well some other command, like instead of making a dot or a period, it's going to automatically unselect your writing utensil and hop off the keyboard. That happened to me several times during lecture, which was one of the frustrating things. So, definitely those things, [unintelligible] there's probably some things that they could still work on.

13) Yeah, yeah, because, you know, everybody's different, everybody has their own style, so for those, who, for instance, are very to the point, and don't take everything down that's on the blackboard, this would be a way to still create a file that they have all their notes, but it'll be, I guess, right at their disposal, if they need it. And, I think that's what I'm getting towards, is people who don't take everything down, this may be a really useful

tool, and they can get away from using paper and having to purchase additional materials, so, in the long run, the *very* long run, it may save you money.

14) Other than enjoying the experience and thank you for the opportunity of using an iPad, I think that's it.

Interview 4

- 1) The Ipad.
- 2) 'Cause I don't really mess with anything like that and I thought I would give it a try.
- 3) I really didn't have any expectation about it 'cause I never really thought about it.
- 4) I do not usually take notes, so I do not have any differences.
- 5) I'm gonna have to say no.
- 6) Well since the processing speed of such a device is still pretty low for what it is, I found my note taking to be much more sloppy and more time consuming. Keeping up with my writing, it just kinda estimated; it was not fluent writing so that made it difficult. Sometimes the "t" would not cross and scratch it multiple times. Sometimes I did an "e" real quick and it became just a line. Stuff like that. Flipped over tried to do just keyboard note taking and I got looped on the board with that because it was taking so long. Math not like keyboards.
- 7) Adjust to the maximum I could get out of it, I'd say a couple class period.
- 8) I do not take notes at all.
- 9) (Since he does not take notes at all, I did not ask him this question).
- 10) Yes I did look on to that when I was looking up things like, uh, for polynomial range, looked back through those, mainly examples, or those things, I looked back on because the books

don't usually go through those too much.

11) No, no, maybe a couple generations further when it is able to keep up with the person's hand writing.

12) Well, as I previously, try to find some way to get a pen back so you have an actual point to it instead of just like a round ball on the end. I think this one is more of a software thing but have some type of keyboard where you can switch on to the math symbols.

- What app did you use for note taking?

DocAS, which is limited for the free version and they didn't tell me upfront so I got four different files saved and then it said "oh wait you can't save anymore." Thanks for telling me. Hahaha.

13) No, not for math, maybe if you were in a different field it would be more useful cause then you can go with the keyboard.

14) Nope.

Interview 5

1) I went ahead and went with the iPad.

2) Um, mostly because I already was used to taking notes electronically and a couple of other people wanted the little pens that recorded and that was, hopefully would have been a little more familiar to me I thought [unintelligible] figured I could work with either one so I went with the one that was more common.

3) Um, I didn't really know for sure what to expect. I hadn't done much with, with, most of my notes before had been taken on either a notebook computer or a tablet and so I didn't

really know how well, how well an iPad would do. I didn't, I didn't have a whole lot of expectations one way or the other.

- 4) Um, the main differences from what I used before, were, for one, I had been able to before set up different keyboard shortcuts like, maybe, like alternate and control would do Greek characters or alternate and shift would do mathematical characters and that was either, didn't happen on the iPad or I didn't know how to do it. So I'm not sure if that's just me being unfamiliar with how Apple works or if that's, or if that's something that, that it just doesn't do. It seemed like a pretty good little device, it, but it was, the other difference that I noticed is the note-taking software that I found was fairly friendly, but it was rather difficult to get the notes out as anything else, so they were pretty much in the iPad and it took somebody else showing me how to do that, to show me what I was missing to be able to email them.
- 5) Um, I would definitely say, compared to what I've done before, it's, it's a comfortable piece of technology to use. It feels like you're carrying a notebook, a paper notebook, around with you. It's, it's fairly light. It's, I like the little stand, that you can stand it up and write on it at an angle, that was, that made it comfortable to use. Um, it was, yeah, those were the, those were the main things that made it easier. The keyboard was, was ok. I've used external keyboards before, it's about the same as the others.
- 6) It already answered in question 4.
- 7) Um, for me to get used to it? Probably within the first, maybe, 20 minutes of using it, I had, I knew most of my way around it.
- 8) Um, usually what I do with my class notes is, I will go back through them and I will re-write my notes afterwards, and try to, try to put them into a concise format. I will, and

then I will go through my homework with my re-written notes and if there's a problem I can't do with my re-written notes, I go back to the original notes and try to fill in the gaps. That's my usual technique. This particular semester is not a good example of that, because I was very pressed for time. (Do you study from your notes?) Yes, usually I do.

- 9) Um, to a degree it did, and that was one of the, one of the things that was a little frustrating with it, was not being able to get the notes. I was used to having my notes, being able to move them from device to device fairly easily, and having this just in the iPad, I was finding I had 2 or 3 things open at once trying to find what I was, where I could put the notes.
- 10) Yes, I did use those. Those, those are what I ended up doing, once I could figure out how to get them out of the iPad. (So you studied from them?) Yes.
- 11) Um, yeah, I, I would say for math, something that would produce, produce, like, integral summations, things like that, the symbols, would, which. Somebody, somebody who knows how to program Apple could probably make an iPad do that. I, There are sev-, there are things that can do that, for like for a tablet PC or notebook that are out there, but for, for just like a general class, I could see how something like that would work as a pretty effective replacement for a paper notebook. The stylus was a bit hard to control, so if it would be something that the person was already used to typing, they would be better off, 'cause control, writing with precision was difficult. (symbols) Yeah, in typing, I don't have any symbols. I was hoping, and it didn't happen, that I could draw the symbol and then type in the other part.
- 12) Um, the big one for note-taking for math would be the symbols. The other one would be to go with a, with a stylus that actually had a point on the end, and it knew when you

were touching it with the stylus, versus just resting your hand on the screen, 'cause then you could, I've had machines that could do that before and they are much easier to write on. You don't have to hold your hand slightly above, and it gives you a whole lot better control. That would be the main, main thing I could see as improving it. Um, some sort of way of, some way of getting your notes saved in a fairly easy to use format, like a pdf or, and some way of just copying them out, not having to emailing them to yourself would be nice, but that actually turned out to be the, turned out to be the paid feature of the software that was turned off in the free version.

13) I used something called "doc as light." D-o-c, a-s, which was fairly nice, but like I said, I was a little surprised when certain features I would expect to, didn't work.

14) I'd probably migrate back to the, back to the way I was doing it before, 'cause the computer I had before does the symbols on it. It does at least some of those things a little better and everything on there is saved in usually a form, usually saved as a text file, or, or, like a Word file, so it's very easy to open, very easy to export.

15) Um, yeah, I would say if they were familiar with it, yeah. I see how it could help them. It's, I could see too, uh, with the application I had, it let you save individual notebooks, too, so instead of carrying, if you had a number of classes that you needed to take light notes in, you could have, instead of carrying around a whole stack of notebooks, you could carry around 1[unintelligible], and that would be, you know, I could see some advantage there.