C-Print Tablet PC Support for Deaf and Hard of Hearing Students

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Abstract: This presentation describes a recent advance of the C-Print classroom captioning system so that it works with a Tablet PC. C-Print is a classroom captioning service that is increasingly being used to support students who are deaf/hard of hearing (D/HH) who are placed in general education classrooms. C-Print provides approximately 700 hours of service each week to D/HH students in general education classes at the Rochester Institute of Technology, and is the most widely used captioning system at the postsecondary level in the United States. The support service is also used in many secondary school classrooms. The presentation will include evidence from four studies that have determined that the C-Print Tablet version is feasible to implement in classrooms and that it benefits D/HH students' communication access and learning.

Students who are deaf or hard of hearing (D/HH) and who attend general education, or mainstream, classes along with hearing peers require classroom support services to have access to classroom discussions. Often a sign language interpreter has provided this support. Students who are D/HH also require supports to retain material after class in order to do homework, etc. Notes taken by others, a peer or professional notetaker, for use after class have often provided this form of support (Hastings et al., 1997). A service that is increasingly being used, which provides support for some students who are D/HH, is real-time speech-to-text transcription (Stinson et al., 1999).

An additional consideration in supporting access and learning in mainstream classes is the ability of the support services and the student to address the barrier of simultaneous presentation of multiple sources of visual information. For example, science classes may sometimes be difficult for D/HH students because they include graphical information, such as figures, etc., and teachers often talk while presenting this information. As a result, the D/HH students may miss important information because they cannot simultaneously attend to the display and the teacher's comments, and support services may have difficulty capturing this information (Marschark, Sapere, Convertino, & Seewagen, 2005). Use of the recently developed tablet PC is likely to increase notetaking and speech-to-text support services' capability to address this challenge and to increase the effectiveness of these services. Use of tablet PCs may significantly improve support services for D/HH students, especially when a class includes both spoken and graphical information, such as most science, technology, engineering and mathematics (STEM) classes.

This presentation describes a recent advance of the C-Print real-time speech-to-text captioning (transcription) system so that it works with a tablet PC. C-Print is a classroom captioning service that is increasingly being used to support students who are D/HH who are placed in general education classrooms. C-Print provides approximately 700 hours of service each week to D/HH students in general education classes at the Rochester Institute of Technology (NTID, 2008), and is the most widely used captioning system at the postsecondary level in the United States. The support service is also used in many secondary school classrooms. Previous versions of the software and support service that used standard laptops did not easily accommodate non-verbal (graphics) information. Research with these

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earlier versions documented the need for graphics support (Elliot, Stinson, McKee, Everhart & Francis, 2001; Elliot, Francis, Stinson, Coyne, & Easton, 2005; Elliot, Stinson, Easton, & Bourgeois, 2008).

C-Print technology uses standard laptop and Tablet PC computers. A trained service provider uses the word-abbreviation feature in C-Print Pro™ to closely capture lecture information. Specialized software, C-Print Pro, allows transformation of phonetics-based abbreviations into full words on the computer screen and produces a real-time display that the student can read on a laptop computer. The electronic file can also be saved and used for review after class.

Two options for using C-Print with a tablet PC have been developed: (a) a notetaking option and (b) a captioning option. With the notetaking option, students view notes in real-time on a tablet PC as they are being recorded by a notetaker. In the second option, in which tablet technology is used with captioning support, a service provider uses a tablet PC to provide graphical information side-by-side with the text on the student's computer display. Examples of real-time notes and speech-to-text plus graphics notes are shown in Figures 1, 2 and 3. This presentation reports the results of four mixed-method field studies, two with secondary students and two with postsecondary students, conducted to demonstrate the feasibility of providing C-Print support to D/HH students in general education classrooms.

Study #1

Method

Design

This study was a mixed-method study involving D/HH middle school and high school students (grades 7-11) enrolled in mainstream classes with hearing peers. Each student received a 5-week trial of either real-time tablet notetaking or C-Print speech-to-text captioning with graphics. Researchers conducted classroom observations and interviews with the students and their teachers. Teachers also completed ratings of their students' performance with the tablet services as compared to their performance without the tablet support service.

Participants

Real-time notetaking. The real-time notetaking group included seven students (5 females, 2 males), and their classroom teachers (n=7). The students had a mean grade level reading ability of 10.64 (*SD*=4.65), as assessed by the Mini-Battery of Achievement (Woodcock, McGrew, & Werder, 1994). Their mean pure tone average hearing loss in the better ear was 63.29dB (*SD*=18.21). Prior to the start of the trial students used the following support services in class: FM (n=6); notetaker (n=5); and sign language interpreter (n=2). The trials were conducted in the following classes: gr. 7 Math (n=1); gr. 7 Science (n=1); gr. 8 Math (n=1); gr. 9 Math (n=1); gr. 10 Chemistry (n=1); gr. 10 Geometry (n=1); gr. 11 Algebra (n=1).

C-Print captioning with graphics. Eight students (3 females, 5 males), and their classroom teachers (n=8) participated in this group. The students had a mean grade level reading ability of 12.40 (*SD*=4.24), as assessed by the Mini-Battery of Achievment (Woodcock, McGrew, Werder, 1994). Their mean pure tone average hearing loss in the better ear was 55.75dB (*SD*=28.77). Prior to the start of the trial students used the following support services in class: C-Print captioning (without graphics) (n=3); FM (n=2); notetaker (n=3); and sign language interpreter (n=3). The trials were conducted in the following classes: gr. 7 Science (n=2); gr.8 Math (n=1); gr. 10 Algebra (n=1); gr. 11 Chemistry (n=1); gr. 11 Math (n=1); gr. 11 Pre-Calculus (n=2).

Procedures

Observations and *interviews*. Prior to the interviews, a researcher from the project team conducted a one-day class observation for each student enrolled in the project. The observation occurred in the fourth or fifth week of the trial in order for students and notetakers to become accustomed to the real-time notetaking support service. Detailed field notes were recorded concerning topics such as the physical setting of the classroom, use of the technology, and social interactions. Interview questions were semi-structured and topics pertained to using the real-time support service and use of the notes after class.

Additional questions emerged from the class observation. Student interviews were conducted in the presence of a certified sign language interpreter, if necessary. All interviews were audio-tape recorded and transcribed verbatim. Interviews lasted between 30-60 minutes.

Teacher ratings. As part of the interview, classroom teachers were also asked to rate their students' performance with tablet support relative to their performance without tablet support. The ratings were on a 5-point scale, with 1=much less than average progress, 3=average progress, and 5=much better than average progress.

Analysis

Observation field notes and interview transcripts and were analyzed for recurrent themes, following the content analysis techniques of Bogdan and Biklen (1998). Data from the teacher ratings of student performance were examined using descriptive statistics.

Results

Student Perspectives

Real-time notetaking was a new and different alternative for the students in the study. Prior to the study, no one had experienced real-time notetaking, although 5 out of 7 students had received traditional notetaking services. Real-time notetaking meant that the student was able to observe the notetaker's notes as they were being created, and that the students were able to augment the notetaker's notes as well. The students were receptive to and positive about the real-time experience. Students compared their real-time experiences to their previous experiences as in the following quote:

Student: It's sort of hard because I need to, if I miss something I don't get to see it or anything. And that's what I thought I found nice about the Tablet, I could see what was happening, being written at the same time as the teacher was talking. So it was nice, if I missed anything, I could be able to tell, I could see what was going on.

In addition to being able to read the notetakers' notes, students were able to add their own markings to the notes, including highlighting, making notations for themselves, typing, and drawing. Students were also able to communicate directly with the notetaker during class if necessary with an "instant message" feature. Students in the real-time notetaking group were very positive about the opportunity to mark their own notes for a variety of reasons, including creating a sense of ownership of the notes, making the notes more clear by using color, and allowing students to more carefully document procedures, such as steps in a math problem.

One of the innovations that became available later in the captioning with graphics trials was the capacity for worksheets or other electronic media (e.g. PowerPoint slides) to be uploaded to the captionist's display to be incorporated into the student display and notes. This aspect of the software was only tried in one class. The biggest deterrent to uploading worksheets was the fact that most instructors did not have electronic copies of the work or that they were unable to give hard copies to the captionist prior to class. However, we did receive feedback from one trial. The following quote is from the student about her experiences working with the uploaded worksheets.

Interviewer: Okay there is something else special. You were the very first person to actually successfully have the worksheets on the computer. Tell me what that was like?
Student: I thought that was really cool! It was like a mini version, and I was writing on it and um, I like seeing C. (captionist) writing on the teacher's notes and then that way I can add to them myself, and also when I got the notes at home I could have my own notes but I could have C.'s notes too… I guess the best way to explain this is when I had the hand written notetaker notes, I have to, like at the end of the day, she would have to decide which day she was going to give me the packet. You know. And this was great, because I could get the pages that we did that day, that day at home.

Teacher Perspectives

From the perspective of the classroom teacher, students appeared to benefit from the real-time experience as well. For example, students' class participation seemed to improve as well as grades. Teachers felt that students benefited from the input of the notetaker's active presence and interaction in the notetaking process. Examples of these observations are shown in the quotes that follow:

Classroom Teacher: She answered more questions in class. She was much more willing to raise her hand. Even her other notetaker had mentioned that to me that she saw more participation in the class than she had ever seen. Her test grades went up, her homework was better completed, all improvements.

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Classroom Teacher: I did like the way that she was able to put down a little quick question mark, if she didn't understand something, and I liked how G. (notetaker) sometimes said "don't ask me, ask the teacher". Because I thought that that link … was pretty powerful. Yes she could quickly get across "hey wait a minute, I don't understand". But then someone was redirecting her and helping her focus with "how do I figure that out".

Teacher Ratings of Student Performance

Classroom teachers rated student performance with the tablet in comparison to the students' performance without the tablet (1=much less progress, 2=less progress, 3=average progress, 4=better than average progress, 5=much better than average progress). With 3.0 being the mid-point anchor indicating similar accomplishments with or without the tablet, these teacher ratings indicate that students performed slightly better, on average, with the tablet than without the tablet, with the greatest gains in class participation. Teacher ratings were not significantly different from one another in the two groups. Results are displayed in Table 1.

Discussion

Interviews with students and their classroom teachers yielded information on a wide variety of topics relating to the real-time notetaking experience. Of particular interest were topics relating to the use of real-time notetaking in class, using the software to mark the text, and training to use the tablet and software. Overall, responses to the trials were very positive and both students and their teachers perceived real-time notetaking as a beneficial support service.

Results from the captioning plus graphics trials also yielded positive feedback from students and teachers. Similar to the real-time notetaking trials, classroom teachers perceived that the captioning with graphics support service helped their students to maintain better focus during class and that student participation changed for the better during the trial. One innovation introduced during the captioning with graphics trials was the capacity to import worksheets or PowerPoint slides into the display. Limited but positive feedback was received about this innovation. Further research should be conducted on the ease and effectiveness of this feature. Overall, responses to the captioning plus graphics trials were positive and both students and their teachers perceived captioning with graphics as a beneficial support service.

In both trials, classroom teachers' ratings of student performance supported the interview data, suggesting that students benefited from the real-time notetaking, especially in the area of class participation

Study #2

Method

Design

This current, ongoing study is a randomized, controlled study involving D/HH middle school and high school students (grades 6-12) enrolled in mainstream classes with hearing peers. The study is taking place in schools in California, Massachusetts, New York, and Pennsylvania. Students are randomly assigned to one of 3 groups: (1) tablet real-time notetaking; (2) speech-to-text captioning with graphics;

and, (3) regular support services called for in the student's Individualized Education Program (IEP) with no additional tablet support service.

Participants

Ninety students will participate in this study. To date, 27 students have participated, using the service for a number of different science and mathematics classes, including: AP Calculus, Biology, Chemistry, Geometry, Intermediate Algebra 2, Math, and a combination Math/Science class. Other characteristics of the students are presented in Table 2. At this point in time, there are no significant differences between the groups on these characteristics.

Procedure

Student activities. Each student in the groups 1 and 2 receives a 5-week trial of either real-time tablet notetaking or C-Print speech-to-text captioning with graphics. If the students have other support services indicated in their IEP, those services remain in the classroom during the trial period (see Table 2). Students in the control group do not receive tablet support during the experimental period. Following the trial period students respond to a questionnaire that includes both closed- and open-ended questions about the trial including comprehension and use of software features.

Teacher ratings. Teachers also complete two ratings of their students' performance: (a) with the tablet services and (b) without the tablet support service. Teachers of control group students complete similar ratings about student performance at 5-week intervals. The ratings were on a 5-point scale, with 1=much less than average progress, 3=average progress, and 5=much better than average progress. The experimental groups are counter-balanced: half of the teacher ratings without the tablet service are done before the tablet service begins, and half of the teacher ratings are gathered 5 weeks after the tablet service trial ends.

Analysis

Data are analyzed using descriptive statistics, analysis of variance, *t*-tests and chi-squares as appropriate.

Results

Preliminary results based on current data collection (approximately one-third of the sample) are presented below.

Student Comprehension of Class

Students in each condition were asked to assess the percentage amount of their ability to comprehend the class (overall), the teacher, the teacher when they could not see the teacher's face (unable to speech-read) and student comments. More students in the speech-to-text group understood at least 80% of the class material, including teacher's, and other students' comments, than did the other two groups. Preliminary analysis suggests that overall understanding of the class is trending toward significance. Detailed information is displayed in the Table 3.

Student Use of Software

Students were asked to describe how often they used the software for taking their own notes or adding to the notetaker's or captionist's notes (1=never, 2=rarely, 3=sometimes, 4=most of the time, 5=every class). Students in both experimental groups reported using the software sometimes: real-time notetaking (n=10, *M*=2.70, *SD*=1.636); captioning with graphics (n=8, *M*=3.00, *SD*=1.069). Participants in the real-time notetaking group have thus far preferred the "copy and paste" function (n=5) while the captioning plus graphics group prefers to write or type their own notes (n=5). Students in both groups agree (1=strongly disagree—5 =strongly agree) that they would recommend the tablet services to other students: real-time notetaking (n=10, *M*=3.70, *SD*=1.252); captioning with graphics (n=8, *M*=4.38, *SD*=.518).

Students were also given the option to write comments about their experience. The following quote is an example of the comments written by students in the trial:

Was easier to understand what I was doing for Math and homework problems because things were color-coded and was very detailed on what needed to be done.

Teacher Ratings

For the two tablet groups, preliminary analysis shows a significant difference between teachers' ratings of academic achievement with and without the tablet, showing that teachers felt that students performed better with the tablet than without the tablet: with the tablet M=3.45, SD=.912, without the tablet M=2.91, SD=.811 (t=2.421, df=21, p=.025).

While there are too few students to appropriately assess for significant differences at this time, students in the tablet notetaking group appear to have fared better with the tablet than without the tablet for course grade, academic achievement, learning new vocabulary, and class participation. Students in the speech-to-text with graphics group were rated higher for academic achievement and class participation with the tablet. Students in both tablet experimental conditions did better than the control group in terms of course grade. Table 4 shows these ratings by trial condition.

Discussion

Preliminary analyses of this ongoing study suggest that middle and high school students enrolled in mainstreamed classes who are D/HH have greater comprehension of class proceedings when they use either tablet real-time notetaking or speech-to-text with graphics support services. Students used the tablet software and would recommend either the real-time notetaking or captioning plus graphics services to other D/HH students. Preliminary analysis of teacher ratings of student performance also suggest that students do better academically with these supports as compared to a control group who did not receive tablet-based notetaking or captioning support services.

Study #3

Method

Design

Field trials were conducted at one university and one community college campus in order to determine the feasibility and usability of captioning with graphics as a support service. Quantitative and qualitative data were collected to assess student experiences with the tablet.

Participants

Eleven D/HH postsecondary students participated in this study. Seven students were enrolled at a university campus in a Northeastern U.S. city and 4 students attended a community college campus in the Southeastern U.S.. Students were enrolled in the following courses alongside their hearing peers: university level {Materials Science (n=1), Discrete Math (n=2), Organic Chemistry (n=2) and, Programming for Information Technology (n=2)}; community college level {Mathematics for Liberal Arts Majors (n=1), Fitness and Wellness (n=1), English Composition: Writing Research Papers (n=1), and Psychology of Personal Effectiveness (n=1)}. All the students who participated in this trial normally received captioning (without graphics) as a support for these classes.

Procedure

Prior to the start of the trial, students received 30 min of training in using the tablet PC by a member of the research team. Students received the C-Print with graphics support service in their designated class for a 5-week trial during their 10-week (university) or 15-week (community college) course.

As students completed their classes they completed an on-line questionnaire. The on-line questionnaire was developed using on-line survey tool software created at the university. The questionnaire included 36 multiple choice, Likert-type scale, and open-ended questions about the tablet trial experience and student background.

After the students completed the on-line questionnaire, they completed an e-mail interview (Seymour, 2001). The e-mail interview is a series of approximately 30 open-ended questions about the experience. Standard questions are asked of all participants and other questions are customized based on individual responses to the on-line questionnaire. Students received the questions by e-mail. Once the students responded, the research team followed-up with additional questions, paralleling the structure of an in-person interview.

Analysis

The on-line questionnaire responses are analyzed using descriptive statistics. The e-interviews are analyzed using content analysis techniques whereby major themes are extracted from respondents' answers based on major topics covered in the interviews (Bogdan & Biklen, 1998).

Results

Questionnaire

Tablet use. Among the 11 respondents, 2 students used the tablet about half the time, 5 usually used the tablet, and 4 students used the tablet always. Students either used the tablet to fill in missing information (n=4) or switched between the instructor or interpreter and the tablet (n=5). One student only watched the tablet and one student did not respond to this question. Students described the frequency of their own notetaking on the tablet. Three students did not take notes for themselves. Three students took their own notes sometimes, two used the tablet for notetaking in almost every class, and three used the tablet during every class session. The tool that was used most often was the ability to draw (n=6), while 3 students used highlighting most frequently and one student preferred copying and pasting captionist notes.

Students rated the ease of use (1=very difficult, 5=very easy) of the features of the tablet such as highlighting, copying and pasting, writing own notes, and drawing as either easy or very easy: highlighting (n=11, *M*=3.27, *SD*=2.195); copy and paste (n=10, *M*=2.0, *SD*=2.582); write own notes (n=11, *M*=3.0, *SD*=2.098); draw (n=11, *M*=3.36, *SD*=1.804).

Helpfulness of tablet. Students rated their agreement about helpfulness on a 1-5 Likert-type scale (1=strongly disagree, 5=strongly agree). All students agreed or strongly agreed that they were able to identify the important information during class while using the tablet (n=11, *M*=4.09, *SD*=1.446). Similarly, students agreed that having both the captioning and the graphics displayed during class helped them to put together the lecture and graphic information, understand class concepts, and understand the teacher's explanation of the graphics (n=11, *M*=4.09, *SD*=1.466). Most students also agreed that having the tablet helped them learn vocabulary for the class (n=11, *M*=3.82, *SD*=1.401). Students also agreed or strongly agreed that they would recommend this service to other students (n=11, *M*=4.55, *SD*=.688). In addition, students felt that the notes produced with the tablet that they received after class were very helpful (n=11, *M*=4.45, *SD*=.688). Student comments on the helpfulness of the tablet included these quotes:

I found the tablet laptop a far better approach to just using captioning on a normal laptop. It makes the course more interactive and I learn more that way.

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I would say, with practice student can improve their way of taking notes and understanding the material, like I did.

E-mail Interviews

The e-mail interviews gave students an opportunity to expand on some of the topics in the questionnaire.

Specific aspects of the software. A number of aspects of the tablet C-Print software are new to the students. For example, being able to write on the captionist's or notetaker's notes, having access to pre-entered worksheets and PowerPoint slides, and viewing captioning and graphics simultaneously. The following quote typifies students' comments about the ability to add to captionist's notes or to make their own notes:

I loved the fact that I could see the notes from the note taker as they were being taken that helped with the understanding. I also loved how I could write over them or correct something if it was wrong.

A key feature of the tablet C-Print software is the ability to both caption and capture the graphics presented in class, allowing all the information is presented in the same visual space. Students appreciated this feature a great deal. As one student explained, having both representations on the screen streamlines student learning because:

It makes things go easy… we deaf or hard of hearing we waste most of our time understanding interpreter or reading C-Print notes and then looking up at the board. I could see what's going on the board and what the professor's saying simultaneously.

The tablet PC is able to capture both the verbal information and the visual information that is presented in class, which is particularly important in STEM classes. For example, material covered in a chemistry class is very visual as well as verbal, and the following quote illustrates student approval for the software:

The notes I got through the tablet PC is that I could see the diagrams at the same time as the C-Print and that definitely helped me visualize the material better which is a significant help in the understanding especially organic chemistry since most of it requires the use of pictures, and diagrams rather than just words.

Discussion

Student feedback was generally positive from both the questionnaires and e-interview methods.

The questionnaire focused on the usability of the tablet and its perceived helpfulness to the students. Students consistently used the tablet throughout the trials, watching the tablet mostly to fill in missing information. Student notetaking activity with the tablet was also frequent and students found the notetaking features to be easy to use.

In general, students felt that the tablet was helpful to them. They were able to identify important information presented in class on the tablet and felt that the merger of verbal and visual information helped the students to comprehend course material. Most students would also recommend the support service to others.

The e-mail interviews gave students the opportunity to share more insights and feedback about their classroom experience with the tablet and C-Print software. The feedback was very positive. Students felt that the software allowed them to better understand the concepts presented in their classes as well as making the learning process more fluid because all information was captured in the same visual space. The software also gave students the independence to take notes for themselves to the extent that they are able. The students believed that the tablet helped to support their learning and is an important innovation and learning tool that addresses the needs of students who are deaf and hard of hearing enrolled in classes with peers who are hearing.

Study #4

Method

This study involves the distribution of notes that are specially produced with Tablet PC technology and the C-Print speech-to-text service (C-Print notes) to all members of the class in a postsecondary setting, regardless of whether the students are hearing or D/HH. The study is designed to evaluate the effect of the C-Print notes upon student learning in undergraduate STEM courses and to demonstrate universal design for learning principles (Scott, McGuire, & Shaw, 2003). The study also intended to assess the benefits of table C-Print notes for students with other learning challenges such as an identified learning disability (LD) or for those who are English language learners (ELL).

Design

The study compares student outcomes in two sections of the same course (introductory statistics) taught by the same instructor in successive quarters. In the experimental condition, all students receive notes after class created by C-Print captionists and research team notetakers using tablet PCs and the C-Print Pro software application. Notes are posted on the instructors' "myCourses" website for the class. In the control condition, students do not receive the notes.

Procedures

Class notes distribution and data collection. During the first week of class the professor administered a pre-test for the course and a member of the research team recruited participants in both experimental and control group classes. Letters of informed consent were signed by students in both experimental and control groups that allow researchers access to student records including standardized test scores, student grades, and documented disabilities (if applicable).

In the experimental group courses, notes were recorded using tablet PCs and the C-Print Pro software during class by (a) a trained C-Print captionist who captured the spoken dialogue of the course, and (b) a member of the research team who recorded the graphical information that was written on the board or overhead projector. After class, the captionist e-mailed the text to the notetaker who merged the graphics with the text. The final version of the notes was posted in the courses' "myCourses" website that is only accessible to students enrolled in the course. The notes were posted within 24 hours of the class session.

At the end of the academic quarter, students completed a questionnaire that included both closed- and open-ended questions concerning the students' notetaking behaviors, uses of notes and demographic information. The control group questionnaire contained 34 items, and the experimental group questionnaire contained 38 items. For the control group class, the questionnaire was distributed by e-mail attachment. Based on student feedback, subsequent versions of the questionnaire were posted on the university's on-line survey tool website. If a student did not complete the questionnaire by the time of the course final, the student completed a paper-and-pencil copy of the on-line questionnaire and these results were entered manually into the results database created by the on-line survey tool.

Students received a post-test assessment that included identical questions from the pre-test assessment. The post-test assessment was incorporated into students' final exams.

Data

Data collected from both experimental and control groups include: pre- and post test results; a self-report questionnaire on note taking and note usage habits and demographics; information on course grades from school records; and, for the experimental group courses only, frequency of note viewing as monitored by the on-line "myCourses" application.

Analysis

Data are analyzed using descriptive statistics, *t*-tests, χ^2 tests and ANOVAs as appropriate.

Results

Participants

Students were paid $25 to participate in the study, which they received when they completed the questionnaire. In the control group class 25 out of 36 students participated in the study. In the experimental group class, 31 out of 34 students chose to participate. Information about the participants in the two classes is summarized in Table 5. It should be noted that the students in the two classes are similar in most characteristics; in the experimental group class, there were significantly more second-year students. In the control group class, there were significantly more third-year students.

Pre- and Post-Tests

Pre-test. The pre-test is a 15-item multiple-choice test. Reliability for the pre-test for the control group was Cronbach's α = .661, and for the experimental group Cronbach's α = .5617. Pre-test results for the control group: (n=24), *M*=77.78, *SD*=16.40 and for the experimental group: (n=32), *M*=38.47, *SD*=17.037. The pre-test scores of the control group and experimental group were compared using t-tests for independent samples. The pre-test scores of the two groups were significantly different, with the mean score of the control group being significantly higher than that of the experimental group. Control group (n=24, M=77.78, SD=16.408); experimental group (n=32, M=38.47, SD=17.037); t=8.680, df=54, p=.000.

Post-test. The post-test is a 20-item multiple-choice test that included all 15 items from the pre-test as well as 5 additional items. Control group results from the post-test including only the original 15 questions from the pre-test are as follows: reliability (Cronbach's α = .597), post-test results: (n=24), *M*=80.00, *SD*=14.97. Control group results from the full post-test (pre-test plus an additional 5 questions): reliabilty (Cronbach's α = .695), post-test results: (n=24), *M*=79.58, *SD*=14.885. Experimental group results from the post-test including only the original 15 questions from the pre-test are as follows: reliability (Cronbach's α = .3825) post-test results: (n=30), *M*=72.20, *SD*=14.184. Experimental group results from the full post-test (pre-test plus an additional 5 questions): reliability (Cronbach's α = .4929), post-test results: (n=30), *M*=71.00, *SD*=12.959. The post-test scores of the control group and experimental group were compared using t-tests for independent samples. The post-test scores of the two groups were significantly different, with the mean score of the control group being significantly higher than that of the experimental group. Control group (n=24, M=80.33, SD=15.689); experimental group (n=30, M=72.20, SD=14.184); t=1.997, df=52, p=.05.

Difference between pre- and post-test scores. The pre-test and post-test (pre-test items only) scores were compared using a paired-samples *t* test. The *t*-test was performed on test results in the control group for the 24 students who remained in the class (1 withdrawal). The difference between the pre-test and post-test scores were not significantly different: pre-test (*n*=24; *M*=77.78; *SD*=16.408), post-test (*n*=24; *M*=80.33; *SD*=15.689), *t*= -1.870, *df*=23, *p*=.074.

In the experimental group, the pre-test and post-test (pre-test items only) scores were compared using a paired-samples *t* test for the 29 students who remained in the class (3 withdrawals). The difference between the pre-test and post-test scores was significantly different: pre-test (*n*=29; *M*=40.86; *SD*=16.028), post-test (*n*=29; *M*=71.69; *SD*=14.152), *t*=-11.917, *df*=28, *p*=.000. It should be emphasized that while there was no significant difference in pre- and post-scores for the control group, there was a significant difference in the pre- and post-scores for the experimental group.

Final Course Grades

Final course grades were gathered for both the control and experimental groups. Values were assigned to letter grades: A=4, B=3, C=2, D=1, F=0. The mean final grade for the control group was (n=24) *M*=3.17, *SD*=.963 and for the experimental group (n=30) *M*=2.83, *SD*=1.085. The mean final grades for the two classes were not significantly different from one another (*t*=1.178, *df*=52, *p*=.244).

Questionnaire

Both groups completed questions relating to their motivation in the class. The control group answered questions concerning their use of notetaker notes (if they were used), and the experimental

group answered additional questions about their use of the C-Print notes for the course. The results for these questions are summarized below.

Motivation for course. All students were asked four questions concerning their motivation for the course. Results for these questions are displayed in Table 6. Students were asked to rate their agreement (1=strongly disagree, 5=strongly agree) with the following three statements: (a) it was important for me to learn a lot in this course (b) I was very interested in this class; (c) I really worked hard in this class. *T*-tests of independent samples did not show significant differences between the two groups on the responses to these questions.

Additionally, students were asked how much time they spent studying for the course during an average week (1=no time at all, 2=less than one hour, 3=1-2 hours, 4=2-3 hours, 5=more than 3 hours), meaning that the average time studying for this course in the control group was between 2-3 hours per week but that the average time studying in the experimental group was slightly over 1-2 hours per week. A *t*-test of independent samples for the mean time spent studying was significantly different for the two groups (t=5.882, df=53, p=.000).

Use of notetaker versus C-Print notes. In the control group, students who received notetaker's notes received notes created by hand by paid student notetakers. Students in the experimental group received notes created with the C-Print notetaking service. We compared responses from students in both groups regarding their use of the different notetaking services. Five students in the control group course used notetaker's notes. All students enrolled in the experimental group course had access to the C-Print notes through the university on-line tool "myCourses." We were able to monitor the number of student views of the notes for 16 class sessions. Across the 16 class sessions, the range of student views of notes was between 0-56, with a mean of 9.23 views (n=30, SD=13.587).

Students were asked about how often they used their notes (1=never, 2=seldom, 3=about half the time, 4=usually, 5=always). Students in the control group reported that they used their notes about half the time (n=5, M=3.20, SD=1.304). The mean usage for C-Print notes was similar to that of the notetaker notes (n=30, M=2.41, SD=1.150). The mean usage of the two groups was not statistically significant (χ^2=2.139, df=4, p=.710).

Respondents were asked if they could identify the important information after class using the notetaker's or C-Print notes (1=strongly disagree, 5=strongly agree) and whether the notes were helpful to the students. Students in the experimental group were more likely to be able to identify important information after class using C-Print notes (n=30, M=3.33, SD=1.709) as compared to students in the control group class who used notetakers' notes (n=5, M=2.60, SD=1.949). This difference was statistically significant (F=33.121, df=1, p=.000).

In addition, students were asked whether notetaker or C-Print notes were helpful to them (1=strongly disagree, 5=strongly agree). Students in the experimental group were more likely to agree that C-Print notes were helpful to them (n=30, M=3.47, SD=1.358) as compared to students in the control group class who used notetakers' notes (n=5, M=3.20, SD=1.483). This difference was statistically significant as well (F=40.689, df=1, p=.000).

Comments about C-Print Notes

Students had the opportunity to comment about the C-Print notes on their questionnaires. The following quotes are illustrative samples from the students and demonstrate the universality of the notetaking support for all students.

D/HH Student: *Absolutely wonderful. If I missed something in my own notes I referred back to the C-Print notes to see what I missed*.
LD Student (with ADHD): *Loved them! They were so helpful*.
ELL Student: *Very useful especially if I missed something in my notes. I can always refer back to C-Print notes.*
Student with no identified disabilities: *Very, very helpful!*

Discussion

In the field study with the introductory statistics classes, students were generally similar, with the exception of a significant difference in the number second- and third- year students in the two classes. The experimental group class had more second-year students, while the control group had more third-year students. It is possible that this difference in college experience may have accounted for some of the differences in outcomes in the study. For example, students in the control group reported that they studied more than the students in the experimental group. In addition, students in the control group attended class more often.

Student experience may have accounted for some additional outcomes in this study. In the control group, students began the course with high pre-test scores, and there was not a significant gain in knowledge to the post-test, suggesting that students already had background knowledge in the course content area. However, in the experimental group, with a greater number of "younger" students, there was a significant improvement from pre-test to post-test score.

Despite differences in college experience, final grades for the course were not significantly different between the two classes. Again, this may be due to factors such as the maturity of the control group class and the fact that the control group class reported studying more for the course than the experimental group did. It is also possible that the C-Print notes provided additional information to students in the experimental group and this information helped level the field between the two classes. The experimental group students were more likely to be able to identify important information from the C-Print notes compared to students in the control group who were using hand-written notetaker notes, and experimental group students found the C-Print notes to be more helpful than students who were using handwritten notes in the control group.

In conclusion, the provision of C-Print notes to the experimental group appeared to be beneficial to the students. In comparison with a control group class with more college experience, students in the experimental group fared as well as the comparison group with regard to final grades and showed significant improvement in their knowledge of course material when considering pre-to post-test scores while the control group did not show the same gain in knowledge.

General Discussion

This presentation describes the evolution and application of tablet PCs for real-time notetaking in secondary and postsecondary classrooms. The smaller pilot studies (studies #1 and #3) allowed developers to introduce new software features as they became available (i.e., incorporating worksheets) and testing the service in a variety of educational settings (secondary, community college, and university). The larger studies (studies #2 and #4) are testing the effectiveness of the tablet as a learning tool for different purposes (real-time notetaking versus captioning plus graphics) and for a variety of different students (D/HH, LD, ELL and others). Further research will enable the advancement of the software and deepen our understanding of how notetaking software and support services can enhance student learning for many diverse student groups.

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Figure 1
Sample of Real-Time Notetaking – Middle School

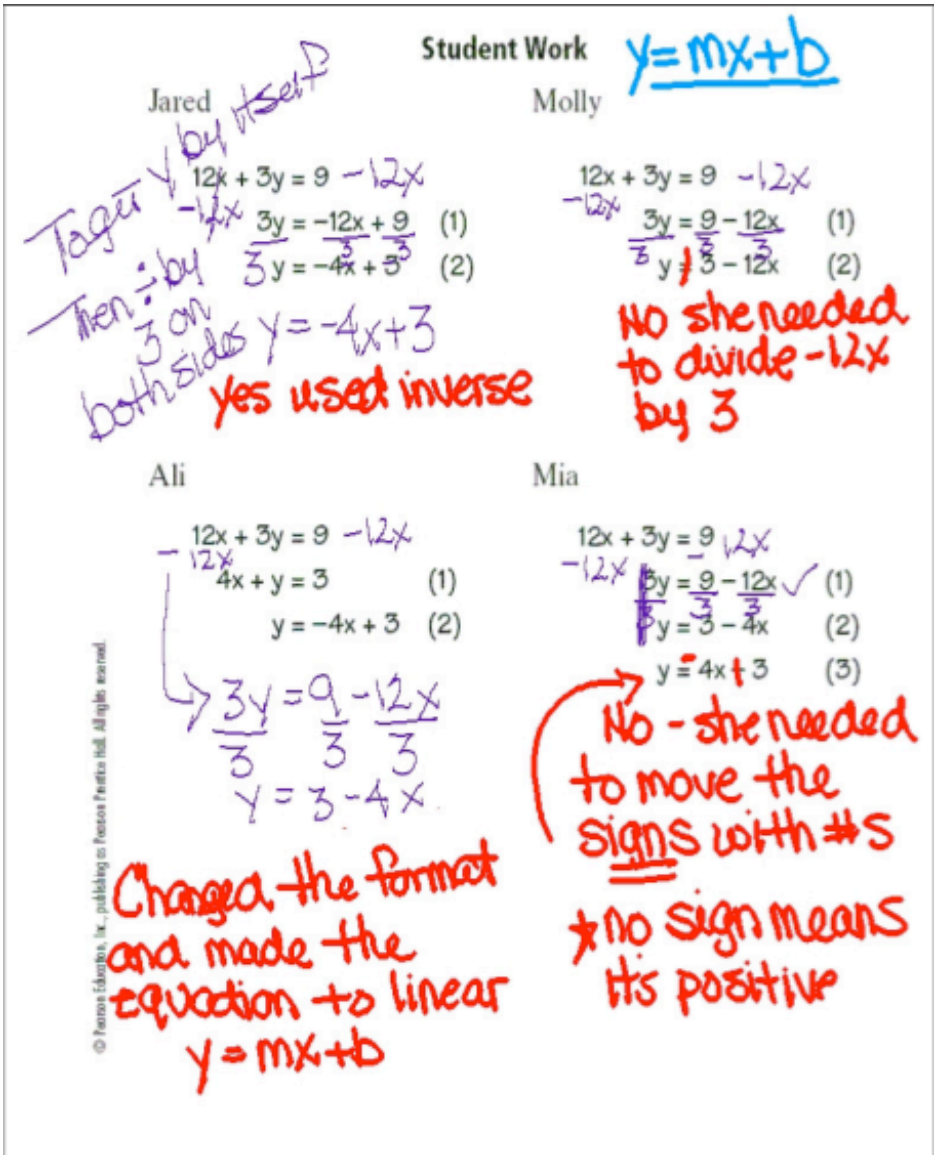


Figure 2
Speech-to-text captioning with graphics-Middle School

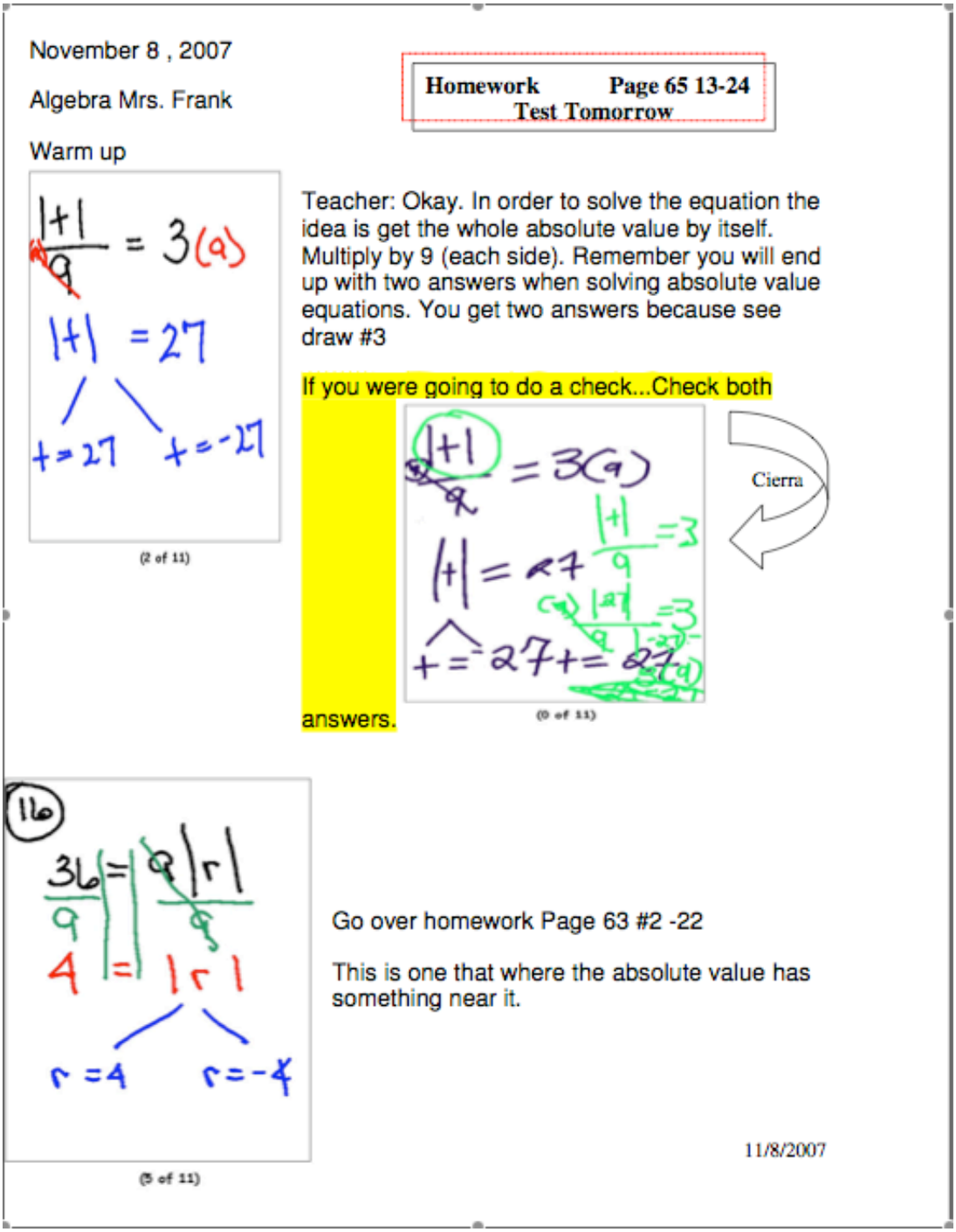


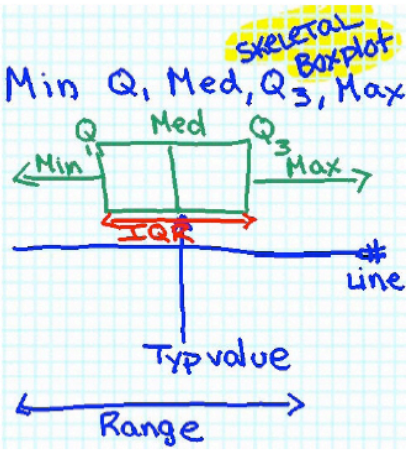
Figure 3
Speech-to-text captioning with graphics-College

How else is the IQR in the quartiles helpful? The answer is creating another graph called the **boxplot.** It is a way to visualize a 5 number summary for your data.

Boxplot – Graph of a 5 number summary.

Five numbers that help us describe our data set are minimum, Q_1, median, Q_3, and maximum.

- A boxplot requires a box.
- Along the number line we will find Q_1 and Q_3.
- In-between is the median, which is represented by a line inside the box.
- Outside the box there are lines, or whiskers that extend to the minimum and maximum.



This is a *skeletal boxplot.*

You should notice we can easily identify a typical value on a boxplot; it is marked by the median. You can notice how spread out the data is (minimum and maximum). Or we can look at the IQR, which is the width of the box. We can also get a sense o whether the data is symmetric. Look at the boxplot around the median.

Table 1
Study #1 - Classroom Teachers' Ratings of Student Performance with Real-Time Notetaking

	Real-time notetaking (*n*=7)	Speech-to-text with graphics (*n*=8)	*t* (*df*=13)
Academic Achievement	*M*=3.29, *SD*=1.25	*M*=3.63, *SD*=.518	-.703
Learning new vocabulary	*M*=3.43, *SD*=.787	M=3.38, *SD*=.518	.158
Class participation	*M*=3.71, *SD*=.951	*M*=3.88, *SD*=.641	-.389

Table 2
Study #2 - Student Characteristics

	Real-Time Notetaking (n=10)	Speech-to-text captioning with graphics (n=9)	Current support service (control group) (n=7)
Grade level reading (*M*, *SD*)	8.3 (1.889)	8.56 (1.740)	8.86 (2.340)
Pure tone dB average hearing in better ear (*M*, *SD*)	65.83 (22.404)	63.66 (26.127)	62.27 (16.093)
Regular Support service: C-Print	2	2	2
Regular Support service: FM	5	4	2
Regular Support service: Interpreter	4	2	3
Regular Support service: Notetaker	2	0	1
Regular Support service: None	0	1	2

Table 3
Study #2 - Student Comprehension During Trial by Condition

M (*SD*)	Real-Time Notetaking (n=10)	Speech-to-text with graphics (n=8)	Control Group (n=7)	*F* (*df*=2)
% Understanding class overall	76 (24.129)	88.75 (11.260)	62.86 (24.300)	2.850*
% Understanding teacher	73.50 (25.172)	91.25 (9.910)	78.57 (21.157	1.746
% Understanding teacher w/o seeing teacher's face	72.00 (33.599)	88.75 (12.464)	52.50 (36.856)	2.246
% Understanding other students	68.00 (31.903)	78.75 (24.749)	55.71 (29.921)	1.158

*p=.079

Table 4
Study #2--Teacher Mean Ratings of Student Performance by Trial Condition

	Tablet Notetaking (n=10)		Speech-to-text w/Graphics (n=9)		Regular IEP (n=7)	
	With Tablet	Without Tablet	With Tablet	Without Tablet	Time 1	Time 2
Grade in class *M* (*SD*)	86.60 (5.562)	83.13 (9.125)	80.75 (14.897)	84.38 (11.275)	77.83 (12.937)	80.96 (15.010)
Academic achievement (1=much worse; 5=much better)	3.7 (.823)	2.63 (.916)	3.22 (.833)	3.14 (.690)	3.0 (1.000)	3.0 (.816)
Learn new vocabulary (1=much worse; 5=much better)	3.22 (.833)	3.0 (.577)	3.12 (.835)	3.14 (.690)	3.14 (.900)	3.14 (.900)
Class participation (1=much worse; 5=much better)	3.20 (.632)	2.75 (.886)	3.00 (1.000)	2.86 (.900)	3.14 (.900)	3.43 (.787)

Table 5
Study #4--Gender, Racial/Ethnic Background, Year in School, and Declared Major

Characteristics	Control Group, Spring 2008 (n=24) n (%)	Experimental Group, Fall 2008 (n=31)	χ^2 (*df*=1)
Gender			.727
Female	10	16	
Male	14	14	
Race/ethnic background			
African-American	1	1	.026
Asian	2	6	.821
American Indian	1	0	1.274
Hispanic	2	0	2.596
White/Caucasian	18	20	.444
Year in school			
First	2	0	2.744
Second	1	13	10.683*
Third	13	8	4.461**
Fourth	6	6	.139
Fifth	1	2	.183
Majors by College			
College of Applied Science & Technology	5	10	1.607
College of Business	3	2	.373
College of Liberal Arts	5	3	.908
College of Science	4	7	.644
Computing & Information Sciences	5	3	.908
Imaging Arts & Sciences	2	1	.492
Not Otherwise Specified	0	1	.907
Self-Reported Disabilities			
Deaf/Hard-of-Hearing	5	10	1.038
Learning Disability	1	0	1.27
English Language Learner	4	7	.365
Physical Disability	1	0	1.274
Behavioral Disability	0	2	1.662

*p<.01, **p<.05

Table 6
Study #4-Student Motivation Questions

Question	Control Group (n=24) *M* (*SD)*	Experimental Group (n=35) *M* (*SD)*	*t*
Important to learn a lot in this course	4.21 (.932)	4.29 (.783)	-.355
I was very interested in this class	3.54 (1.179)	3.45 (1.028)	.302
I really worked hard in this class	4.04 (.859)	4.03 (1.048)	.036
Amount of time spent studying during an average week	3.92 (1.108)	2.23 (1.087)	5.882*

*$p<.01$