Using Tablet PCs to Integrate Graphics with Text to Support Students Who Are Deaf and Hard of Hearing

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Abstract

In recent years speech-to-text systems have provided support services to a growing number of deaf and hard of hearing (d/hh) students in mainstream classrooms. Science, technology, engineering, and math (STEM) courses provide some of the most serious challenges to providing appropriate support services to d/hh students. While there is evidence to confirm that speech-to-text systems have successfully supported access and learning for some d/hh students, a remaining challenge for support service providers is the inability to capture graphical information in conjunction with the text. Other support services are equally challenged to provide d/hh students with sufficient access to STEM material. This paper describes the use of Tablet PCs and the C-Print system to provide two support service options for students who are d/hh: real-time notetaking and speech-to-text with graphics. Included are: descriptions of the C-Print Tablet software with graphical input capabilities; information about research trials conducted using the Tablet options, and a discussion of how integration of graphics will affect the role of students and service providers.

In recent years, increasing numbers of deaf and hard-of-hearing (d/hh) students are being educated in classrooms alongside hearing students (National Center on Education Statistics, 1999; Gallaudet Research Institute, 2002). Students receive a variety of support services to accommodate their access and communication needs in these inclusive classrooms. As content material becomes more sophisticated and dense in secondary and postsecondary courses, the need for appropriate support services that match access needs with instructional methods becomes more crucial to in order to foster d/hh student success.

A growing concern for educators and the science and technology community is the challenge to make science, technology, engineering, and math (STEM) courses more accessible to students with disabilities, including students with hearing loss (National Science Foundation, 2003). An instructional method common across many STEM disciplines is the use of graphical or non-text-based information including formulas, symbols, charts, graphs, drawings, and the like. Very often, the instructor will, for example, have a formula or illustration on the board or displayed on an overhead and will explain facets of the concept that is visually depicted. True comprehension of the subject material requires that the student looks at the drawing *and* attends to the explanation simultaneously. This requirement can be extremely challenging for d/hh students in mainstream classrooms.

In addition to the challenges imposed by teaching methodology in STEM courses, attributes of three common support service options contribute to these challenges for d/hh students for two reasons. First, d/hh students experience constraints related to the technology of the support services especially when used in STEM courses. Second, competing visual demands for the students occur when d/hh students receive speech-to-text services, or when they speech-read the instructor or watch an interpreter, or, when d/hh students use both an interpreter and notetaker. All add to the barriers faced by students in STEM classes.

Limitations of speech-to-text systems. A growing number of deaf and hard-of-hearing (d/hh) students receive speech-to-text support services in mainstream classrooms. These systems provide a word-for-word or meaning-based display of what is said in class, as well as options for saving the text after class for study. While there is evidence to confirm that speech-to-text systems have successfully supported access and learning for some d/hh students (Elliot, Stinson, McKee, Everhart, & Francis, 2001; Elliot, Coyne, & Stinson, 2006; Elliot, Stinson, Easton & Bourgeois, 2008), a remaining challenge for support service providers is the inability to capture graphical information in conjunction with the text. Research on the usability of speech-to-text systems consistently reports student frustration with speech-to-text systems due to their lack of graphics (Elliot, Stinson, McKee, Everhart, & Francis, 2001; Elliot, Stinson, & Coyne, 2006.)

The lack of graphical information in speech-to-text displays is keenly perceived when speech-to-text support is offered in STEM classes because these courses often include spoken (i.e., vocabulary, explanations, etc.) and graphical information (i.e., diagram, formulas, etc). Because speech-to-text systems are text-based, service providers are not able to capture the graphical information in real time. As a result, deaf/hh students may miss important information.

Limitations of speechreading and interpreters. While increasing numbers of d/hh students use speech-to-text support services, there are still many circumstances in which d/hh students either rely on speech reading the teacher or use an interpreter. In the situations in which a student relies on speech reading or the interpreter alone, there are many times when students may miss an the opportunity to connect the visual information with the spoken (interpreted) message because the instructor's face may be turned away from the student so the student only sees the visual information or because the interpreter is not in the same visual space as the illustration. In both these scenarios, students may miss key information necessary to comprehend the explanation (Marschark et al., 2005).

Limitations of notetakers. Still other students rely on the combination of an interpreter and notetaker for access in mainstream courses. It is common practice for notetakers to take notes by hand, on multipart, pressure sensitive paper, and for students to receive those notes at the end of the day (Hastings et al, 1997). The readability of the notes can be influenced by the legibility of the notetaker's handwriting as well as how well the notes come through the multiple layers of pressure-sensitive paper. Notetakers may also complete worksheets or need to do additional drawings that have to be integrated into the notes packet that the student receives, but explanations relating to those handouts might not be incorporated in the notes. Usually, students and notetakers interact very little, and students do not know what notes have been recorded until they receive them.

Therefore, each of these widely available support services for d/hh students, speech-to-text support, interpreter only, and interpreter with notetaker have limitations for students, especially when used in STEM classroom settings where instruction involves simultaneous, multiple presentation modes. These limitations create barriers for d/hh students that may inhibit student success in STEM courses.

Tablet PC options. A promising new generation of laptop technology, called the Tablet PC, is now available. Tablet PCs provide both typing and graphical—(handwriting and drawing) input. In addition to the standard input option (i.e., typing) of a traditional laptop, Tablet PCs allow the user to write and draw directly on the screen of the laptop, using a special pen, called a stylus.

The C-Print research and development team has adapted C-Print® software to work with the tablet. By expanding the capacity of C-Print software, we have created *two new options* for real-time support. First, by providing students and notetakers with wirelessly networked tablets, C-Print software can now support handwritten, real-time notetaking, which allows students access to their notes as they are being created; and, second, C-Print software can now incorporate graphical information with a real-time display of the spoken dialogue text. With both options, a student using a Tablet PC can add their own notations to the notes, graphics, or text that is being created by the service provider. Worksheets and other electronic media created by the teacher can be incorporated into the real-time display and notes as well.

Use of Tablet PCs will likely help improve service providers' ability to address the challenges of providing support services to d/hh students—especially when class include both spoken and graphical information—such as in most STEM classes. These are the types of classes in which traditional typing only C-Print has sometimes had limited effectiveness; the software modifications will increase the effectiveness of speech-to-text services, as well as creating new opportunities for more traditional, handwritten, notetaking services.

This presentation discusses the use of Tablet PCs and the C-Print system to provide two support service options for students who are d/hh. The first option provides speech-to-text support and graphical information in real-time. The second option provides notetaking support that is viewed in real time by students who are d/hh.

The presentation includes a demonstration of the C-Print Tablet software, featuring the graphical input capabilities. In addition, presenters will demonstrate how graphical information can be integrated into the real-time display, two-way communication, and notes distributed after class, and discuss how the integration of graphics affects the role of students and service providers. The presentation will include findings from a recent study that examines the benefits of using Tablet PCs to provide real-time notetaking and speech-to-text with graphics support services.

Recent research with C-Print Tablet software indicates that it increases academic performance, improves attentiveness in class, and increases student involvement. Presenters will share information about research trials, including: feedback from students, teachers, and service providers; academic performance data; and lessons learned from the research trials.

Methods

Materials

Networked tablets for notetaking. In using the C-Print Pro tablet software for notetaking, the support notetaker and student each have tablets with 10-12" displays that are compatible with Windows XP tablet version, such as the IBM **X41** Tablet PC, for *hardware*. These computers have mobile or detachable keyboards, internally built wireless capabilities for networked communication, and a stylus with adjustable settings. To support notetaking, the C-Print Pro tablet *software* has a graphics pane that enables students to impose their own notes in real-time on a transparent overlay "on top" of the notetaker's information that is displayed on the student's tablet. Transfer of information between tablets occurs over a network through the Internet protocol

(TCP/IP) along with a proprietary protocol. Student and notetaker are able to access the different layers for writing and viewing, but the protocol regulates who can add input to a particular layer.

Software for real-time notetaking. The primary application that the project used for the work with networked tablets with notetaker support is Corel Grafigo 2 (Corel, 2005). A key reason for selecting this application is that it is desirable for students to be able to impose their own notes in real-time “on top” of the notetaker’s information that is displayed on the student’s tablet. Grafigo has an “onionskin” transparent overlay that enables students to add and save their own marks and notes as the support notetaker is writing notes. Text windows may be easily created for typed input, and a Library feature is available to organize saved documents. Once created, notes can be distributed in various formats (i.e., .html, .pdf, .doc). Figure 1 below shows a sample of real-time notes created with the software.

The project also used Microsoft’s Advanced Networking Pack for Windows XP to enable the peer-to-peer technology to support wireless communication with Grafigo. Grafigo has received favorable review as a simple graphics program that works well collaboratively (Brown, 2003).

During the notetaking trials, the C-Print Pro software application that supports real-time notetaking was developed to replace Grafigo in future research. However, during the research reported for this paper, real-time notetaking trials used the Grafigo software.

Software for captioning with graphics. C-Print Pro™ tablet software was used for these trials. The software allows a range of ways to produce information, from text to drawing. It differs from previous versions of C-Print Pro software and other speech-to-text services that produce only text. Once created, notes can be distributed in various formats (i.e., .html, .pdf, .doc). Figure 2 represents speech-to-text notes with graphics produced with the new C-Print software.

Figure 1. Real-time Notes Sample

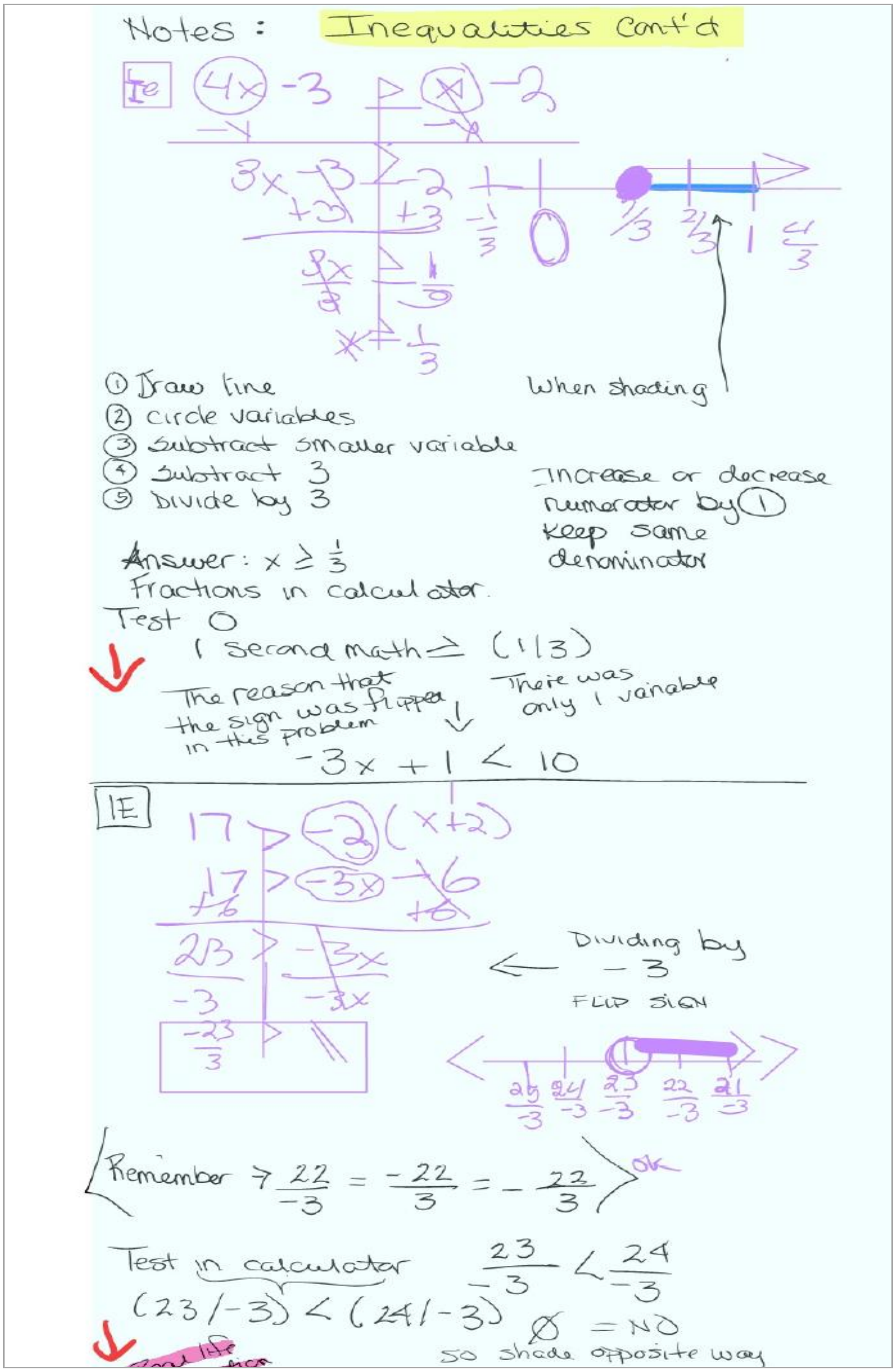


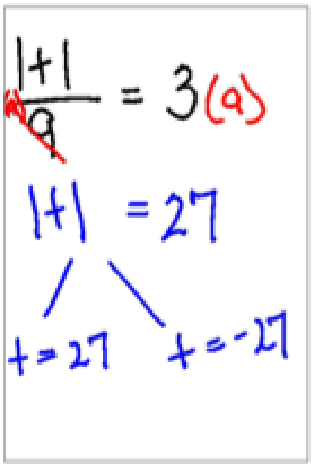
Figure 2. C-Print w/Graphics Notes Sample

November 8 , 2007

Algebra Mrs. Frank

Homework Page 65 13-24
Test Tomorrow

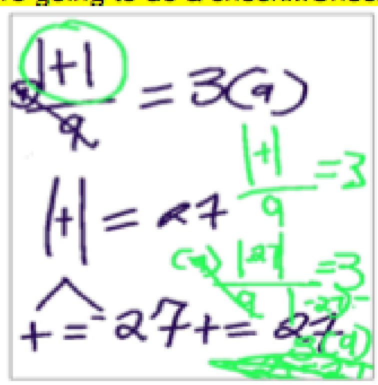
Warm up



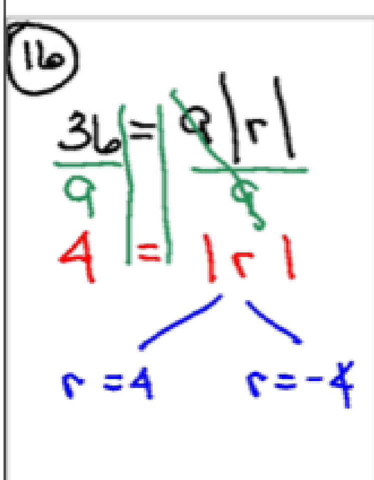
(2 of 11)

Teacher: Okay. In order to solve the equation the idea is get the whole absolute value by itself. Multiply by 9 (each side). Remember you will end up with two answers when solving absolute value equations. You get two answers because see draw #3

If you were going to do a check...Check both answers.



(9 of 11)



(5 of 11)

Go over homework Page 63 #2 -22

This is one that where the absolute value has something near it.

11/8/2007

Participants

Middle and high school students, (grades 7-11) who are deaf or hard of hearing participated in this study, along with their classroom teachers, and itinerant teachers of the deaf (TODs). Fifteen students (8 females, 7 males) participated in total: 7 students in trials using tablets for real-time notetaking, and 8 students who used the tablet for speech-to-text (captioning) plus graphics. All the students were enrolled in math or science general education classrooms with hearing peers. The students had a pure-tone average hearing loss of 60.40 dB in the better ear (*SD*=25.068). Mean grade level reading ability was assessed at 11.58 (range grade 5-16.9, SD=4.3676) using the Mini-Battery of Achievement (Woodcock, McGrew, & Werder, 1994). Additional student characteristics are displayed in Tables 1 and 2 below.

Table 1. Student Characteristics for Students in Real-time Notetaking Trials

						Additional Support Services Received Prior To/During Trial			
Sub #	Sex	Grade	Reading Grade Level	Better Ear HL	Course	Interpret	Note taker	FM	C-Print
001	M	7	7.9	M→Sev	Science	√		√	
002	F	10	>16.9	Mod	Chemistry		√	√	
003	F	10	8.6	Mild	Geometry		√	√	
004	F	8	13.7	Mod	Math		√	√	
005	F	9	15.5	Mod	Math			√	
006	M	7	6.9	M→Sev	Math		√	√	
007	F	11	5.0	Sev	Algebra	√	√		

Table 2. Student Characteristics for Students in Captioning with Graphics Trials

						Additional Support Services Received Prior To/During Trial			
Sub #	Sex	Grade	Reading Grade Level	Better Ear HL	Course	Interp	Note taker	FM	C-Print
008	M	8	n/a	Sev	Math	√	√	√	
009	F	7	n/a	Prof	Science	√	√		
010	M	11	16.2	Mild	Math				√
011	M	11	>16.9	Mod	Pre-Calculus				√
012	M	7	13.3	Mod (CI)	Science	√	√		
013	F	11	>16.9	Mod	Pre-Calculus			√	√
014	F	10	7.1	Mod	Algebra				
015	M	11	6.9	Mild	Chemistry				

Procedure

Students were identified as potential participants by their TODs. Informed consent was obtained from parents or guardians by the TODs. Prior to the start of the in-class field trial, individual students, classroom teachers, TODs and other support staff, and parents or guardians met with two members of the research team (notetaker or captionist and researcher). During this meeting, the technology was demonstrated and the research procedure was explained. The notetaker or captionist met with the student for an additional half hour before the classroom trial began for additional training.

Classroom trials lasted for 5 weeks. During the trial, students received either the tablet real-time notetaking service or the captioning with graphics service. Any other services that were stipulated in the student's IEP (such as an interpreter, FM, etc.) were also maintained during the 5-week trial. During the real-time notetaking trials, the notetaker took notes in class with tablet and the notes were communicated instantly to the student's tablet. This is different than normal notetaking in which students only see the notes after class. Students added their own notes as needed by adding marks on top of the notes produced by the service provider.

Similarly, during the captioning trials, captionists used the C-Print software to create speech-to-text notes with graphics and the text or graphics were communicated instantly on student's tablet. These notes differed from the usual speech-to-text notes because they included graphics as well as the text of the spoken dialogue. Students added their own notes as needed by adding marks on top of the text or illustrations produced by the captionist.

During the third or fourth week of the trial, the researcher attended one class session. Field notes were recorded. Following the end of the classroom trial, the researcher conducted individual, open-ended, face-to-face interviews with the student, the classroom teacher, and the TOD.

Data Collection

Hearing loss. Data on student hearing loss (unmasked air assessments at 500 hz, 1000 hz and 2000 hz) were gathered from school records.

Reading ability. Data on students' grade level reading ability was assessed with the Mini-Battery of Achievement (Woodcock et al., 1994). This three-section test includes tests identification, vocabulary, and comprehension and takes about 10 minutes to administer. The test was administered to the student by a project researcher.

Communication preference. Students completed a 20-item questionnaire regarding their communication preferences at school and at home, as well as their background and skill in sign language and their use of assistive devices, hearing aids, and cochlear implants.

Teacher rating of student performance. Teachers were asked to rate student performance in academic achievement, learning new vocabulary in the course, and class participation during the trial as compared to their previous performance. The ratings were based on a 1-5 Likert-type scale, with 1=much less than average progress, 5=much better than average progress.

Classroom use. Field notes were gathered during classroom observations. Observational data included topics such as the physical classroom setting; (classroom set-up including student seating arrangement, lighting, etc.) student interactions (student interaction with the technology, other students, and class participation) teacher-student interaction, teaching style, and use of audiovisual materials. Notetaker or captionist behavior was also observed, including interaction with students, teachers, and other supports staff, as well as notetaker or captionist practices. Information gathered during the observations was used during interviews (see below).

User experiences. Semi-structured, face-to-face interviews were conducted with students, classroom teachers, TODs, notetakers, and captionists. A research team member skilled in ethnographic interviewing techniques conducted the interviews. The same individual also conducted the classroom observations. The interview protocols included a predetermined list of topics, but interviewers encouraged interviewees to pursue their own line of thinking. Interviews were also individualized based on information gathered during the classroom observations.

Interviews included the following topics: impact of the Tablet PC technology on understanding and class participation by deaf/hh students; interaction/comparison of Tablet PC with other accommodations and support services (notetaker, interpreter, FM system, etc.); reactions to electronic or paper text, and descriptions of whether/how/under what conditions it is used by students; advantages and limitations of Tablet PC to providing text and notetaking tools. Additionally, students were asked to describe specific ways in which they use the Tablet PC support services.

For each student who was interviewed, the student's TOD and classroom teacher and notetaker or captionist were also interviewed. Total number of interviews included: classroom teachers (n=15); TOD/Resource Room (n=12); notetakers (n=4); captionists (n=4). (Some numbers do not add up to 15 because some notetakers, captionists and TODs served multiple students.) To the extent possible, parallel questions were asked of the teachers and support staff.

For face-to-face interviews with students, an interpreter was present at the interviews, if necessary, to (a) facilitate communication as needed and (b) voice the signing of the interviewer and respondent onto an audiotape. Verbatim, typed transcripts were generated from the audiotapes and reviewed for accuracy by the interviewer.

Analysis

Descriptive statistics were used to analyze quantitative data due to the small number of participants. Qualitative data gathered in the field notes and interviews were analyzed using content analysis techniques described by Bogdan and Biklen (1998). The research team read all field notes and transcripts and, through discussion, developed a set of code categories based on major topics covered in the interviews. Investigators independently coded their field notes and interview transcripts, meeting regularly to discuss and resolve differences in coding decisions. Data analysis was facilitated by the use of HyperResearch software (Researchware, Inc., 2007). The software allowed researchers to generate reports in which interview data was sorted by code categories and themes. This tool allows researchers to prepare analyses of the data that are supported through extensive use of quotations from participants.

Results

Teacher ratings

Teachers rated student progress during the trial compared to their progress before they received the technology. Teachers rated academic achievement, vocabulary, and class participation. To summarize teacher ratings for the 15 students:

- Teachers rated students as progressing better than before, or the same as before: except for one rating for one student, all ratings were for average progress or better.
- About equal numbers of ratings were for better progress than previously and for the same progress as before.
- For two areas, academic achievement and class participation, there were more ratings of better than average progress than average progress.
- For one area, learning new vocabulary, there were more ratings of average progress than better than average progress.

There was no obvious difference in the pattern of ratings for the notetaking option and for the speech-to-text or captioning plus graphics option.

The complete chart for teacher ratings is shown in Table 3, below.

Table 3. Teacher Ratings of Student Performance During Tablet Trial As Compared to Student Performance Without Tablet

Sub #	Much less than average performance	Less than average performance	Average performance (no difference)	Better than average performance	Much better than average performance
001	A			V	P
002			AVP		
003					AVP
004			V	AP	
005			VP	A	
006			AVP		
007			AVP		
008			V	AP	
009			V	A	P
010				AVP	
011			AP	V	
012			A	VP	
013			AVP		
014			V	AP	
015			V	AP	

A= Academic Achievement V= Learning New Vocabulary P= Class Participation

The largest amount of data for the study was qualitative, including classroom observations and interviews with students, their classroom and support teachers, and service providers. Following are several excerpts from these interviews.

Student Feedback

Using tools to remember important information. The tablet software includes tools for marking the text, such as highlighting, and drawing. The following comment shows how the student used the tools to help remember information that is important.

> *Interviewer:* Tell me about those kinds of notes. Did you write, or did you highlight, or did you draw, what did you do?
>
> *Student:* If it's an important thing that's going to be on a test or something, like one time I was drawing a picture of an atom that I was doing for a project so I drew on the table to make sure I remembered and not forget anything that would be important. And other times I wrote down what was going to be on a test so I wrote it down so I could study.

Integration of electronic classroom materials into display and notes. Another feature of the software is the ability to integrate other electronic classroom materials such as worksheets or PowerPoint slides. The following comment reflects how the student said she benefited from seeing the classroom materials, and being able to see the captionist's notes on this sheet. The student also describes her ability to add her own notes to the teacher notes which is referred to as sharing space with the service provider:

> *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.*

Teacher Feedback

Classroom teachers were also interviewed. Several of the teachers remarked that students increased their participation in class, not just in quantity, but also in quality. The following comment shows the qualitative difference—class participation changed from asking questions with the goal of obtaining an understanding to making comments that were based upon already having an understanding of the material being presented.

> *Teacher: Yeah, in terms of her participation, she is a very strong student to begin with and she obviously takes pride in her work. But it seemed like her participation now is less on, "I don't understand this" but more on, "I just want to repeat and want clarification." So her participation though, may not have improved in terms of how many times she was speaking out, but the information she was presenting to the class was more on target than before.*

Service Provider Feedback

Communication between the service provider and the student is another topic that was discussed during interviews. Some providers who used the notetaking option had never communicated with the student during class; the tablet technology was the first time they had experienced this type of student interaction. In the following quote the notetaker explains how she was able to communicate to the student the right way to produce a drawing that the student had been making incorrectly.

> *Notetaker: "Now I see why, oh that really helped me." Things like that the students would say to me. You know, clockwise, counter clockwise drawing arrows, um, one example was I had a student who drawing in clockwise and counter clockwise, she drew it in backwards. So I drew it in the right way so she would know, and she was like, "Oh, thank you so much."*

Lessons Learned

In conducting this small-scale study on adapting C-Print software for use with tablet PCs, many lessons were learned, in particular, from the experiences of notetakers, captionists, and students.

Notetaker perspectives. The biggest transitions experienced in this study were felt by the notetakers, because using a computer to deliver support was a marked difference from traditional service delivery. This change was smoother for notetakers who were more comfortable with technology.

A second, profound difference in notetaker experience related to the ways in which the notetaker interacted with the student. In traditional notetaking services, the notetaker may communicate very little with the student; in the real-time notetaking model, notetakers communicate and interact constantly with students. This new form of notetaking requires negotiation between the notetaker and the student as to how the two will share the space on the tablet "page" and also, who will be responsible for recording content (e.g. student writes down material from board, while notetaker adds commentary or explanation).

Other adjustments that notetakers were required to make included becoming comfortable carrying heavier equipment, taking the time to familiarize oneself with the technology, and adjusting one's schedule with regard to the editing and printing processes.

Captionist perspectives. While captionists have had more experience with C-Print software and laptop technology, changes were still necessary to transition to the tablet. For example, captionists needed to familiarize themselves with the new features of the software and the hardware. They also had to adjust their captioning strategies to decide when it was appropriate to caption or to use the stylus and add information by hand.

Similar to notetakers' experiences, captionists also learned how to negotiate with students about who would record certain information. In addition, in certain circumstances captionists worked more closely with classroom teachers to obtain worksheets and other electronic media before class that could be included on the real-time display.

Student perspectives. Students also experienced role changes associated with the tablet technology. For example, students learned to advocate for themselves in negotiating with notetakers and captionists about what material they (the students) would like to record. Also, students were given the autonomy to take notes or to add annotations for themselves. For some students, these new opportunities were welcome; for others, it was more of a puzzle because the students demonstrated poorer notetaking skills.

Additionally, students had to decide when and how long to look at the tablet. While students expressed a variety of strategies for looking at the tablet, none of the students found it difficult to read the tablet. Depending on the paperwork demands of the class, student wrote more—or less—on the tablet. (For example, in some classes, students were graded on the quality of their notebooks. In these situations, students wrote on the tablet less often.)

Discussion

A variety of support services are available to d/hh students who are educated alongside their hearing peers. In the case of STEM courses, these support services often fall short due to a combination of circumstances, including the nature of STEM educational methods and the unique characteristics of the support services themselves (Marschark et al., 2005; Stinson & Antia, 1999).

A pilot study was conducted involving d/hh middle and high school students who used tablet PCs for either real-time notetaking or speech-to-text with graphics support in STEM courses. Quantitative ratings of student performance by classroom teachers suggested that most students performed at least as well, if not better, using the tablet PC-based support services.

Interviews conducted with students and teachers also referenced positive attributes of tablet-based support services including increased autonomy and more focused class participation for students.

New technology posed new challenges for service providers and students alike. While the software was easy to use, notetakers had the most significant transition to make, moving from a manual system to one supported by a computer. Students and their service providers also encountered new relationships as they negotiated with content and shared notetaking space.

Continued research with these support services will explore the educational impact of tablet-based supports as well as implications of their implementation in STEM classes. It is anticipated that these research findings will add to the improvement of support services for d/hh students and facilitate students' success in STEM.

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