Student Learning with C-Print®’s Educational Software
and Automatic Speech Recognition

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Abstract

Access and communication needs, retention of information, and engagement as active learners in the classroom are all critical factors for the success of deaf and hard-of-hearing students (d/hh) in the mainstreamed classroom. Speech-to-text support services with embedded educational tools such as highlighting, notetaking, and messaging can address these needs. This presentation reports preliminary findings from the results of a multi-method investigation of mainstreamed d/hh middle school and high-school students’ learning with the C-Print speech-to-text support service with embedded educational tools: (a) A multiple-correlational study examining the relationship between use of C-Print and course performance; (b) An observation/interview study examining how students learn with the C-Print Pro software and text display; (c) A second observation/interview study examining teachers’ views of the impact of C-Print on student learning.

Preliminary findings from the surveys and interviews suggest that students are using the speech-to-text support service with educational tools successfully. Teachers were pleased with student progress with C-Print as well. Mean scores of teacher ratings of student performance indicate that teachers observed improvements in academic achievement, learning new vocabulary, and class participation.

Research suggests that a speech-to-text support service with embedded educational tools shows promise with d/hh students in mainstreamed settings. Students can make decisions for themselves about the relevance of information and have additional options for access and communication needs. This is a significant contribution to developing deaf and hard-of-hearing students as independent learners, preparing them to become critical thinkers and empowering them to succeed.
Today, the majority of students who are deaf or hard of hearing (deaf/hh) and receiving special education services are educated in public schools; of these, a large number attend general education, or mainstream, classrooms for some or all of their academic subjects (Karchmer & Mitchell, 2003). In order for these students to have a successful learning experience in mainstream classes, three forms of support are important. These supports are in line with principles of universal design for instruction that suggest that successful learning environments encourage interaction and communication in the classroom (Burgstahler, 2002; Scott, McGuire, & Shaw, 2003). First, students need access to classroom lectures and discussions. One way that access is provided is through a sign language interpreter and a second is through a real-time speech-to-text support service. Use of speech-to-text services has grown considerably in recent years (Kavin, 2001; Stinson et al., 1999).

Second, it is important that these students be able to retain information after class in order to do homework, prepare for tests, etc. Hearing students are able to take notes for themselves. In contrast, deaf/hh students often rely on notes taken by others. Often peer or professional notetakers handwrite the notes that are provided to mainstreamed students after class (Hastings et al., 1997). Speech-to-text services provide deaf/hh students a means to remember material by making available saved text that is produced during class.

Third, it is desirable that students be actively involved in the classroom learning (Minskoff & Allsopp, 2003). For hearing students, the ability to take their own notes is a key way that they help themselves be actively engaged and learning, and these notes help students remember their thinking during class (Armbruster, 2000). Although deaf/hh
students may want to only briefly divert attention from watching the teacher, or real-time display of a speech-to-text system, a support that facilitates active engagement and that helps them remember their thinking during class may be beneficial. This idea is supported by recent research with C-Print, which suggests that students who use more text-marking and study strategies perform better on learning tasks (Stinson, Elliot, Kelly, Stinson, & Liu, 2005). Most computer-based speech-to-text support services do not offer students computer-based options for self-notetaking during real-time display. Dramatic changes to the software used with the C-Print speech-to-text system have enabled students to enhance their active learning behaviors while simultaneously using this support.

This presentation shares some of the results of one of a series of investigations that examine the C-Print speech-to-text support service (e.g. Stinson, Stinson, Elliot, & Kelly, 2004). One important way that this research is different from earlier work is that previous studies used an earlier version of the C-Print system that had no special features to support active learning or class participation. For this study, the C-Print system includes the C-Print Pro™ software that includes two-way communication capabilities and educational tools. The networking component sends text from the service provider’s (captionist) to the student’s computer, and it includes a messaging feature that allows for two-way communication between the provider and student separate from the text of the class discussion. The educational tools include an optional split screen for students to take their own notes. A “tag” feature connects these notes to a specific location in the text section of the screen. Students can also highlight important points in the text section. Additionally, the system includes the dual capacity to transcribe speech into text with
automatic speech recognition (ASR) and with a keyboard-based computerized word abbreviation system. To use ASR, the captionist in the classroom with the deaf/hh student(s) dictates into a microphone connected to a laptop computer containing the ASR software. The software converts the sound into text that is displayed on the laptops of the captionist and the student. The captionist also can type the spoken message using the abbreviation system. Students and teachers can view the text with the software after class as well. Text (and notes) can also be e-mailed, posted on the web, or printed for after class use.

Objectives

The study described here had three objectives:

• To implement a computer-based, speech-to-text support service with educational tools and to conduct a usability study to delineate the support needs of deaf and hard-of-hearing students that are critical for classroom access and communication, memory of class content, and active learning goals for success in mainstream educational settings.

• To describe recent findings of a study of deaf and hard-of-hearing middle and high school students who participated in a trial of speech-to-text support services with educational software that is designed to address access and communication, memory, and active learning goals for success in mainstream educational settings.

• To discuss the implications of speech-to-text support services with educational software for students and their teachers in mainstream educational settings.

Methods
This presentation reports some of the preliminary results of a multi-method investigation of mainstreamed deaf/hh high-school students’ learning with C-Print: (a) A multiple-correlational study examining the relationship between use of C-Print and course performance as assessed by teacher ratings and the relationship between students’ use of the software features and course performance; (b) An observation/interview study examining how students learn with the C-Print Pro software and text display, whether with ASR or the abbreviation approach. (c) A second observation/interview study examining teachers’ views of the impact of C-Print on student learning.

Participants

Forty deaf/hh middle and high school mainstreamed students in public schools in grades 5-12 in the West (n=12), Midwest (n=13), and Northeast U.S. (n=15) participated in this study, along with their classroom teachers and itinerant teachers of the deaf. Students were eligible to participate in this study if they were deaf or hard of hearing and did not have C-Print in the target class. Classroom teachers needed to consent to participating in the study as well. Itinerant teachers of the deaf nominated the student participants for participation in the study.

Students received a variety of support services in their classrooms including FM only (n=8), interpreter only (n=11), interpreter and CART (n=2), interpreter and FM (n=1), interpreter and notetaker (n=5), interpreter, notetaker, and FM (n=3), notetaker only (n=5), and no support services at all (n=5). Fourteen of the students had at least one other family member who was deaf or hard of hearing. Nine of the students were from homes where a language other than English was spoken, including Bosnian, 2 Ethiopian Languages (Adare and Trigrina), Spanish, and Vietnamese. The students’ reading ability,
as assessed with the Woodcock-McGrew-Werder Mini-Battery of Achievement (1994), ranged between grade level 1.4 and 16.9. Median grade level on the reading assessment was 7.5, and the mean was 9.5, $SD=5.33$. Seven students did not know sign language at all; of the remaining 33, 21 learned sign language by age 5, and 12 of the students learned sign language between the ages of 7 and 15. Fourteen students in the study had a cochlear implant, and 25 of the students used at least one hearing aid. Mean pure tone average in the better ear was 64.61dB ($SD=36.27$).

Data Sources

Data were collected through school records, student testing, surveys, classroom observations and interviews. Data were gathered from or about all students with regard to reading ability, hearing loss, communication preferences, motivation for success in class, experiences with and without C-Print, and student performance.

Reading ability. Students’ reading ability was assessed with the Woodcock-McGrew-Werder Mini-Battery of Achievement (1994). This is a 3-part test covering the areas of identification, vocabulary, and comprehension. It is administered face-to-face, with students either responding orally or with sign language. The test takes approximately 10 minutes to administer. It offers a comparison of students’ accomplishments relative to other students at their grade level.

Hearing loss. Students’ degree of hearing loss was obtained through audiology reports in school records. We gathered data on loss at 500, 1000, and 2000 Hz levels, or pure tone averages if the more specific data were unavailable.

Communication preferences. Students completed a pencil-and-paper questionnaire concerning communication preferences. This was a 23-item questionnaire
including questions on preferred communication mode in the classroom, family communication, perceived skill in using and receiving ASL and Signed English, and the types of assistive listening devices used by the students.

Motivation for success in class. Motivation for success in class was measured with a 4-item pencil-and-paper questionnaire. Items included questions concerning students’ level of interest in class, perceived importance of doing well in class, amount of effort put forth and the amount of time studying in the past week for the class.

Experiences with and without C-Print. Student experiences with and without C-Print involved paper-and-pencil questionnaires as well. The C-Print questionnaire included 45 forced-choice items plus additional opportunities for students to write open-ended comments. Questions included background information about computer use prior to C-Print, how students used the real-time display of C-Print during class, use of the educational tools in the C-Print software and study behaviors during and after class.

The non-C-Print questionnaire varied in length, depending on the type of support services the student received when C-Print was not present. Questionnaires were available for students who did not have any support services (6 items), note taker only (11 items), interpreter only (5 items), interpreter and note taker (10 items). Common to all questionnaires were questions about the amount of information that the student understood from the teacher and from the student. In note taker situations, additional questions were asked about the amount of information that students received from the notes, whether or not important information could be identified from the notes, and how notes were used for studying.
Student performance. One-page, 6-item teacher ratings of student performance with and without C-Print were also collected at the conclusion of each section of the trial. The six items concerned teacher perceptions of student performance with regard to achievement, learning new vocabulary, and class participation. Teachers were asked to rate their students on a 1-5 scale (1 = least – 5 = most). Two sets of ratings were sought: one which asked the teacher to compare the student’s performance to that of other students in the class, and the second rating to compare the student’s performance relative to her or his own performance when C-Print was or was not present in the class. These questionnaires were distributed to teachers and were mailed back to the researcher.

Classroom observations and interviews. Classroom observations and interviews were conducted with approximately 1/3 of the participants. Students were randomly selected for the observations that were conducted by one of the researchers or field administrators at the West and Midwest sites. When a student was observed in class, students, the classroom teacher, and the student’s itinerant teacher or special education teacher were also interviewed. Field notes were taken of the classroom observation and insights from the observations were utilized in the interviews. Interviews were open-ended, audio-tape recorded, and transcribed verbatim. Certified interpreters were involved with student interviews when necessary.
Procedure

Study design. Students participated in a 10-week study period (roughly 1 marking period.) During this time, either the first 5 weeks or the second five weeks involved a 5-week trial of C-Print speech-to-text support service with educational tools in one of the student’s courses. There was a 5-week period either immediately before the C-Print trial or immediately after the trial when students received their regular, IEP-specified support services, but not C-Print. In addition, for the C-Print input, students either received automatic speech recognition (ASR) or traditional typing with abbreviations. Counterbalancing order of service (e.g., C-Print first, regular services second, etc., and type of C-Print (ASR, typing) yielded four combinations of service. Students were randomly assigned to one of the four combinations. The study design is shown in Table 1.

Table 1

<table>
<thead>
<tr>
<th>Time period</th>
<th>n=20</th>
<th>n=20</th>
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<tbody>
<tr>
<td>5 weeks</td>
<td>Receive C-Print Typing (n=10); ASR (n=10)</td>
<td>Receive Regular IEP services (n=20)</td>
</tr>
<tr>
<td>5 weeks</td>
<td>Receive Regular IEP services (n=20)</td>
<td>Receive C-Print Typing (n=10); ASR (n=10)</td>
</tr>
</tbody>
</table>

Students selected the courses for the C-Print trial in consultation with their itinerant teachers of the deaf. Courses included English/Language Arts and Literature, Science courses including Biology, Chemistry, and Physics, a variety of History/Social Studies courses, and a Spanish class.

Prior to the beginning of the C-Print portion of the trial, students, their itinerant and classroom teachers, and the captionist met together for an orientation concerning the
project. Other participants in these meetings included a researcher, parents, other support team members, and school administrators. At that time, the trial was explained and the student and the itinerant teacher received supplementary materials described below. If a particular C-Print trial was the 2nd 5-week portion of the trial, then the researcher distributed the non-C-Print student performance rating to the teacher at this time, and also administered the non-C-Print questionnaire to the student. If the C-Print trial was the first half of the study period, then teachers and students were advised at this meeting that they would be receiving questionnaires at the end of the 5 weeks. Regardless of the timing of the C-Print trial, students were also informed that they would be given a brief reading test during the trial and that they would be answering additional questions about their C-Print experience, as well as possibly having an interview with the researcher at the end of the C-Print trial.

Following this meeting, the captionist spent a class period observing the class. At this time, captionists determined where they might sit, classroom dynamics, etc. Usually during this visit, other students in the class were introduced to the captionist and the C-Print research. This introduction was handled on a case-by-case basis; sometimes the captionist would do all the explanation, other times, the teacher or the participating student would be involved in the introduction as well. The captionist would also meet with the student outside of class to teach them how to use the software. These meetings lasted up to 30 minutes, depending on the student’s comfort level with the software. Approximately 2 weeks into the trial, the captionist would have another brief meeting with the student and teachers, in order to “fine tune” the experience, with suggestions for changing seating arrangements or other modifications.
Students received the C-Print speech-to-text support service during class. In addition, students had access to the C-Print software outside of class. In cases where students had access to a PC computer at home, students were given a copy of the C-Print client (student) software for their home computer. In cases where students did not have access to a home computer, the software was put on a computer somewhere in the school, for example, in the library, resource room, or computer lab. This additional access allowed students to use the C-Print educational tools outside of class for additional opportunity to actively use their notes.

Materials. The C-Print speech-to-text support service provided students with an individual laptop computer that was networked with the captionist’s laptop. The student display can be partitioned into three sections. The main sections enables students to view the real-time, meaning-for-meaning transcription of dialogue or presentation in the class. The display is retained throughout the class, and students can scroll up or down to read missed information. An electronic copy of the transcription is produced and either e-mailed to the student or produced in hard copy as notes for the student and teachers. The educational tools within the software provide students opportunities for active learning during and after class. A notetaking panel on the display allows students to copy and paste segments of the transcription or to take notes for themselves. “Tags” link these notes with a specific sentence in the text produced by the captionist. Students can also highlight portions of the transcription, with a choice of a rainbow of different colors. The third available pane on the student’s C-Print display is the messaging window. This tool allows the student to communicate directly with the captionist or alerts the captionist to voice questions to the instructor on behalf of the student (much like an IM system).
Figure 1 displays the C-Print captionist and student screens. (Captionist screen above and student screen below.)

**Figure 1**

C-Print Captionist and Student Displays

Students received supplemental materials to help them use the software. During the class periods, students were given 3x5 index cards with reference hints on how to use the software and study tips (e.g., how to do effective highlighting; suggestions for note taking). The student and itinerant teacher also received a 20-page booklet called *The C-Print Survival Guide*. This handout is a user’s manual that includes instructions for the use of the software and a 10-page guide with suggestions on how to use the educational tools (highlighting, “tagging,” and writing one’s own notes).
Data collection. Data for the study were actively collected at several points during the trial. Teacher ratings were collected at the end of the “no-C-Print” and “with C-Print conditions.” Student questionnaire data was collected at the end of the no-C-Print and C-Print conditions. Student reading test and communication preference questionnaire data were collected during the 5 weeks of the “with C-Print” trial. Classroom observations were conducted during the C-Print portion of the trial, usually during weeks 3, 4, or 5. Interviews with students, classroom teachers, and itinerant teachers of the deaf (or special education teachers) were conducted within 2-3 weeks of the conclusion of the C-Print portion of the trial.

Analysis

Quantitative data were analyzed with descriptive statistics (e.g., frequency distributions and standard inferential statistics such as chi square, anova, and paired t-tests). Results are reported for selected items. Qualitative analysis of interviews was done with content analysis (Bogdan & Biklen, 1998).

Results

Student background experience with computers

On the C-Print questionnaire, we asked students to tell us their experience with computers before their participation in this study. Fifty-five percent of the students used computers everyday, and 30% of the students used computers once a week. Twelve percent of the students used computers once a month or less often. Frequency of computer use was not correlated with the student’s grade level. However, students’ previous experience was significantly and positively correlated with ratings on items about their use of the C-Print instant messaging feature ($n=39$, $r=.343$, $p=.033$), and their
ability to identify important information during class using C-Print \((n=39, r=.320, p=.047)\). Previous computer experience was negatively correlated with student use of “help” cards \((n=39, r=-.395, p=.002)\) and students’ rating that the “help” cards were helpful \((n=36, r=-.395, p=.017)\). In the interviews, students also discussed their experiences with computers. Much to our surprise, not all students were as familiar with the computer as we had assumed, and a lack of familiarity or expertise impacted the students’ experiences in different ways. For example, several of the students expressed nervousness prior to the start of the trial, due to lack of familiarity with laptop computers. However, most of the students quickly became comfortable with the laptops and used the software in class.

For other students, lack of typing skill influenced their use of the software. In some cases, it influenced their choice of tool (e.g., highlighting vs. typing own notes). In other cases, lack of typing skill inhibited the student’s use of any of the software tools. For example, consider this student’s decision:

*Interviewer:* Okay. So maybe another one of those reasons that you are not using the typing so much is because it is kind of slow for you?
*Student:* Yeah, ... I can’t type in my own notes that would take way too long, I would be like this and they would be like “okay I am paying attention, oh shoot, I can’t do this”.
*Interviewer:* Right. So, yeah, so it is kind of hard to pay attention to what the teacher is saying and then to type.
*Student:* and to type at the same time. I just can’t do that. Not as slow as I type. ‘Til I get better (at typing).

**Student use of C-Print real-time display**

**Strategies for watching C-Print display.** According to student questionnaires, at least 65% of the students used the speech-to-text support service most of the time during class. In watching the display, almost one third of the students used the display to fill in
missing information with an occasional glance at the screen. Half of the students switched between the interpreter or classroom teacher and the speech-to-text display. Ten percent of the students looked at the screen exclusively. Neither grade level, reading ability, nor communication preference was significantly related to the mode of use of the C-Print display.

**Perceived understanding of teachers and other students.** Access to classroom proceedings is one of the critical elements of support services for deaf/hh students. We surveyed students about their understanding of their class experience (understanding teachers and other students in class) with and without C-Print. Table 2 below shows the percentage of perceived understanding by student participants of their teachers and fellow students.

<table>
<thead>
<tr>
<th></th>
<th>C-Print (n=37)</th>
<th>No C-Print (n=37)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understand Teacher</td>
<td>87.57</td>
<td>79.86</td>
</tr>
<tr>
<td>Understand Students</td>
<td>80.41</td>
<td>70.54</td>
</tr>
</tbody>
</table>

Paired t-tests of these means showed significant differences between students’ self-rated understanding of their teachers with C-Print or with their usual, IEP-specified support services ($t=2.779$, $df=36$, $p=.009$). Students’ understanding of the other students in their class also differed significantly between C-Print and non-C-Print conditions ($t=2.188$, $df=36$, $p=.035$).

We also analyzed the data on perceived student understanding based on the type of C-Print students received, typing or ASR. T-tests showed no significant differences
between mean ratings for students who received typing C-Print and for those who received ASR C-Print for (a) the perceived understanding of teachers (typing, $M=86.7$, ASR, $M=88.68$, $t=-.383$, $df=37$, $p=.704$) or (b) for understanding other students in class (typing, $n=20$, $M=77.25$, ASR, $n=19$, $M=84.74$, $t=-1.279$, $df=37$, $p=.209$).

**Student use of C-Print educational tools**

Students are actively using the educational tools of the service. Students used the educational tools (highlighting, “tagging” or copy and paste, writing own notes) during class with high frequency. Thirty-five percent of the participants used the educational tools 4 or more times during the trial, while 15% never tried them. Among the students who did use the tools during class, highlighting was the most popular tool used, favored by 45% of the students who used the software. Copy and paste and writing one’s own notes were each favored by 15% of the students. There was a significant difference between the use of tools at the different school districts. The students in the Northeastern schools used the software the most frequently, and those in the Western schools used the software the least frequently ($F=7.29$, $df=2$, $p=.002$).

Interview findings show that C-Print helped students to master notetaking skills. For example, this seventh grade student described how highlighting helps her:

*Interviewer:* But, you did do a lot of highlighting and a lot of moving stuff?
*Student:* Yes, I did.
*Interviewer:* So what did you like about those things, those features?
*Student:* That it would help me in the future. And that it would show me that these notes are important. Like when I highlight them. It will get me to do stuff better, like if I am doing a reading assignment, “hey, I know this is important, so highlight it”.
*Interviewer:* So it helped you practice your skills?
*Student:* Yes.
Teacher ratings of student performance

Mean scores of teacher ratings of student performance indicate that teachers also observed improvements in academic achievement, learning new vocabulary, and class participation. Six pairs of t-tests were conducted to test for differences in teacher ratings with and without C-Print. Three of these tests were performed on ratings of a student’s performance in comparison to other classmates. An additional three tests were performed on ratings of a student’s performance in comparison to his/her performance before or after the 5-week C-Print trial. All six comparisons were statistically significant at the $p<.000$ level. Table 3 below displays mean teacher ratings of student performance:

Table 3
Mean Teacher Ratings of Student Performance
With and Without C-Print

<table>
<thead>
<tr>
<th>Topic</th>
<th>With C-Print</th>
<th>Without C-Print</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academic Achievement compared to other students</td>
<td>4.03</td>
<td>3.91</td>
</tr>
<tr>
<td>Learning New Vocabulary compared to other students</td>
<td>3.91</td>
<td>3.77</td>
</tr>
<tr>
<td>Class Participation compared to other students</td>
<td>3.49</td>
<td>3.21</td>
</tr>
<tr>
<td>Academic Achievement of student compared to self</td>
<td>3.69</td>
<td>3.14</td>
</tr>
<tr>
<td>Learning New Vocabulary of student compared to self</td>
<td>3.53</td>
<td>3.00</td>
</tr>
<tr>
<td>Class Participation of student compared to self</td>
<td>3.71</td>
<td>2.94</td>
</tr>
</tbody>
</table>

Teachers discussed the impact of C-Print on their students. Here is an excerpt from the teacher of the student featured above.
Teacher: Well, that's the most positive thing I think that occurred. I had been trying to get her to keep up in the classroom by taking notes by hand. Listening to what was going on and there were certainly times where she was out of focus, off task and etc. The C-Print certainly allowed her to focus more, and to use notetaking skills that she normally would not have used. For example, she began to find out how to highlight on the C-Print. And that was well taken by me because she began to look for key words and phrases, a skill she needed in order to do that.

Discussion

At the beginning of this presentation, we described three critical areas that need to be addressed in providing learning opportunities for deaf/hh students in mainstream classes. Access and communication needs are often supplied by a variety of speech-to-text support services as well as interpreters.

Retention of information is often achieved by notetaking. Most hearing students are able to accomplish this task themselves. Despite the obvious challenge, deaf and hard-of-hearing students may also be expected to take notes without support, or they receive the services of student or professional notetakers. Recent enhancements to speech-to-text support services can help deaf/hh students (who were previously unable to take notes for themselves) to do so. Enabling students to make decisions for themselves about the relevance of information is a huge contribution to developing deaf and hard-of-hearing students as independent learners, preparing them to become critical thinkers and enabling them to continue to advance their education.

As noted, most students used this notetaking feature at least once, and a little more than a third used these features on a regular basis. Two factors influenced the extent that students used these features. One was the familiarity with and skill of the student in using computers. A second factor appeared to be the extent to which staff at school districts supported students using the notetaking feature. Support may have included time
the captionists took to explain the features to students, and the extent to which the teacher attended to the students’ use of the features. The captionists in the Northeast program were part of the research staff and they were more familiar with the features and the materials regarding their use. Although training and monitoring were provided to the staff at the Midwest and Western programs, it does not appear to have assisted staff at these locations to effectively encourage use of the software by the students. Better materials, training, and monitoring are needed to achieve greater use of the notetaking features by students.

Finally, students need to be engaged as active learners in the classroom. A speech-to-text support service that allows students to communicate and facilitates independent learning helps to accomplish that goal. The teachers’ higher ratings of the students’ performance with the speech-to-text system than with their regular IEP-specified support service suggests that the teachers observed positive learning behaviors when the students used the speech-to-text system. These appear to have included perceptions of active involvement, including use of the notetaking features. Teachers also may have observed greater ability to follow classroom discussions and other activities. Additional innovation and improvements to existing support services, and greater awareness of how to utilize existing support services will only help students to achieve their educational goals.
References


