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Empirical Article

Deaf/Hard of Hearing and Other Postsecondary Learners' Retention of STEM Content With Tablet Computer-Based Notes

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Four groups of postsecondary students, 25 who were deaf/hard of hearing (D/HH), 25 with a learning disability, 25 who were English language learners (ELLs), and 25 without an identified disability studied notes that included text and graphical information based on a physics or a marine biology lecture. The latter 3 groups were normally hearing. All groups had higher scores on post- than on pretests for each lecture, with each group showing generally similar gains in amount of material learned from the pretest to the posttest. For each lecture, the D/HH students scored lower on the pre- and posttests than the other 3 groups of participants. Results indicated that students acquired measurable amounts of information from studying these types of notes for relatively short periods and that the notes have equal potential to support the acquisition of information by each of these groups of students.

Students who are deaf or hard of hearing (D/HH), as well as other diverse learners such as students with a learning disability and those who are English language learners (ELLs), face significant communication barriers in science, technology, engineering, and mathematics (STEM) undergraduate courses. These students' cognitive, linguistic, and perceptual characteristics make it difficult to participate in and learn from classroom discussions and lectures. Simultaneously comprehending a lecture and taking notes can be an impossible task in a STEM course if the student also needs to be actively engaged in the class presentation.

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There is extensive research that documents the importance and wide use of students taking their own notes to aid lecture learning. Two comprehensive reviews of this work are those by Armbruster (2000) and Kobayashi (2006); however, all students, not just those with an identified disability, experience difficulty comprehending STEM class information and taking their own notes. Courses in STEM fields use multiple information channels to teach STEM concepts. In STEM classes, students view problems, mathematical formulas, charts and graphs, and laboratory demonstrations with manipulations of materials, computer code, and computer applications in addition to following the spoken word to learn STEM concepts and principles (Gardner, 2002; Marschark, Sapere, Convertino, & Seewagen, 2005). For example, students have been observed in courses such as chemistry where the professor simultaneously (a) lectured, (b) used a PowerPoint display, and (c) displayed models of chemical compounds with an overhead visualizer. In order to comprehend such information and remember it afterward, students typically need to (a) understand what the teacher and other students are saying, (b) follow the graphics (which may be presented simultaneously), (c) integrate the two sources of information, and (d) reinforce and remember for themselves key concepts. Not only must the student capture the information that is presented during class, they must retain their own thoughts about it (e.g., what is important),

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in a manner that allows effective use after class in completing assignments and tests. Usually students attempt to capture the information and understanding by taking their own notes (Armbruster, 2000; Mayer, 2001). Kierwa et al. (1991) suggest that even for students without disabilities, the demands of note taking and comprehension during class may often be too much to ask of most students because the mechanical skills involved with note taking (i.e., spelling, organization on the paper, etc.) may overpower the student's capacity to synthesize and incorporate new learning from the presentation into their own experience. The present study focused on C-Print@ notes, which may address the above challenges by using service-provided notes that improve students' access to a lecture's content during review after class; this study is not concerned with student note taking itself. This study compared the extent that students who are D/HH, those with a learning disability, those who are ELLs, and those without an identified disability learned from special C-Print notes that included text and graphical information and that were produced on a tablet computer. These C-Print notes include what the instructor and students say in class and also the graphical information (e.g., PowerPoint slides) presented during class. Thus, these materials may capture the course material in a comprehensive and thorough, yet condensed manner, and the information is sufficiently detailed so that student may benefit regardless of background and perspective of the individual who uses them. These materials may help students to focus on understanding content during class as opposed to concentrating on recording information for later study. When C-Print notes are distributed to a class, students, to the extent possible, may continue to take their own notes regarding important understandings during class but may be able to focus on learning, rather than on recording all the information that they may need later. Students may use these materials for review after class for clarification, homework completion, and exam preparation.

C-Print is a real-time captioning (i.e., speech-to-text) support service that was originally developed to provide communication access to D/HH students who attend classes with hearing students (Stinson, Elliot, McKee, & Francis, 2000). With this support, the service provider listens to the teacher or students and produces a text display of the message that appears on the D/HH student's laptop approximately 3 s after the words have been spoken. Students can read the display to understand what is happening during class. Students and teachers can view the text or notes (without graphics capability) after class. Many D/HH students use C-Print for communication access and notes as an alternative to interpreting and note taking services (Stinson, Elliot, & Francis, 2008). As this service began to be used around the country as an accommodation for D/HH students mandated by law, service providers also distributed C-Print notes to hearing students who had difficulty comprehending spoken lectures (Simon, 1999; Smith-Pethybridge, 2005). This experience provided the impetus for investigation of acquisition of information from the notes by the four diverse groups of students. In addition, improvements have been made in the C-Print technology, including development of the tablet version that allows graphic input in contrast to earlier versions of C-Print that allowed only typing input. The C-Print notes produced with the tablet version may help address specific challenges to classroom learning that students who are D/HH, those with a learning disability, and those who are ELLs encounter. As examined below, each of the student groups (D/HH, ELL, and learning disability [LD]) exhibits communication and learning needs that converge with one another. These commonalities merit examination in contrast to students without an identified communication or learning need.

D/HH Students

Sign language interpreting, in which the interpreter translates the spoken English into sign language or vice versa to facilitate the communication access of D/HH students, and note taking, in which an individual with normal hearing produces handwritten notes that D/HH students may study afterward, are common support services that postsecondary programs use (Hastings et al., 1997; Marschark et al., 2005; Stinson et al., 1999). D/HH students rely on lipreading the instructor, watching an interpreter, or watching a real-time display of captions to access the instructor's spoken comments. It is extremely difficult to focus visual attention on this information and on taking personal notes simultaneously (Elliot, Foster, & Stinson, 2002;

Hastings et al., 1997). In STEM education, D/HH students may miss important information because they cannot attend to visual displays, such as graphs and charts, and the interpreter or instructor at the same time (Elliot et al., 2002; Hastings et al., 1997; Marschark et al., 2005). In addition, D/HH students' background knowledge may be lacking as compared to hearing students with regard to their preparation for postsecondary science education and students may have limited proficiency in English (Mitchell & Karchmer, 2011; National Technical Institute for the Deaf [NTID], 2006). These limitations may hinder D/HH students' learning in STEM classes.

A few studies have examined D/HH students' use of notes and acquisition of information with notes. Al-Hilawani (1999) and Richardson, MacLeod-Gallinger, McKee, and Long (2000) each used surveys to compare study behaviors of D/HH students in mainstream classes with those of hearing peers. Both studies found that the study behaviors of the two groups were comparable. Elliot et al. (2002) conducted a qualitative study in which they interviewed 36 D/HH high school and college students in mainstream classes about their use of notes. They found that high school students used fewer and less elaborate strategies, whereas college students used more strategies, which were more sophisticated and active.

Marschark et al. (2006) conducted several experiments, including one that examined D/HH college students' retention of information from two STEM lectures. Students viewed the lectures under three conditions: (a) standard C-Print (no graphics), (b) communication access real-time translation, and (c) interpreting. After viewing a lecture, students studied a transcript produced with the corresponding technology or, in the case of interpreting, studied handwritten notes produced by a note taker. Students were tested after viewing the lecture and studying the notes and again 1 week later after studying the notes. There were no differences between retention of information under the three conditions. Stinson, Elliot, Kelly, and Liu (2009) compared D/HH high school and college students' retention of information with C-Print and interpreting. As with the Marschark et al. (2006) investigation, students studied notes or transcripts after viewing the lecture, depending upon the conditions; in this case, however, the lectures involved social science topics. The high school students retained more information with C-Print than with interpreting, whereas the college students showed no difference between retention in the two conditions. Both the Marschark et al. (2006) and the Stinson et al. (2009) studies examined the combined effect of lecture and notes rather than the effect of notes only as is the case in the present study. In addition, the C-Print transcripts in the previous studies included no graphics, in contrast to the present study.

Students With a Learning Disability

Students with a learning disability are attending college in greater numbers than ever before (American Council on Education, 2001). STEM courses depend on a student's facility with language (Burns, 2003; Fathman & Crowther, 2006; Strawser & Miller, 2001). According to Burns (2003), "language is the currency with which higher education is bought and sold. Students who struggle with language—the encoding and decoding of it—have been short-changed in this market" (pp. 178–179). Students with a learning disability often face challenges related to their language skills, such as spelling or visual-spatial organization, or they may have difficulties with motor skill or memory problems (Strawser & Miller, 2001). All of these abilities, as well as fluid reasoning, symbolic representation, and understanding of causal relationships are crucial for success in STEM fields (Strawser & Miller, 2001).

Research on the note taking skills of students with a learning disability at any educational level is sparse, and, in particular, there exists limited empirical research concerning college students with a learning disability (Heiman & Precel, 2003; Hughes & Suritsky, 1993; Igo, Riccomini, Bruning, & Pope, 2006). Even less is known about college students with math-related LD (Strawser & Miller, 2001). Hughes and Suritsky (1993) described one of the few experimental studies conducted with college students with a learning disability; 30 college students with learning disability and 30 college students without a learning disability listened to a 20-min videotaped lecture and took notes. The students without a learning disability recorded significantly more information than the students with a learning disability. In addition, the students without a learning disability used significantly more abbreviations in their notes, and abbreviated a greater variety of words.

Suritsky and Hughes (1991) and others (Heiman & Precel, 2003; Igo et al., 2006; Strawser & Miller, 2001) elaborate a number of skill deficits that may impinge on these students' ability to take good notes including their inability to (a) attend to the lecture, (b) identify important information, (c) understand what is being said, (d) relate new information to existing personal knowledge, (e) organize information in a meaningful way, and (f) record information fluently and legibly. Although it is a widely held belief that the act of note taking promotes encoding for students without a learning disability, experts concede that among students *with* a learning disability, the encoding phase does not appear to be effective and results in little actual learning (DiVesta & Gray, 1972; Igo et al., 2006; Peper & Mayer, 1986; Suritsky & Hughes, 1991). In situations where students do not benefit from taking their own notes, receiving note taker notes is a justifiable accommodation (Igo et al., 2006; Suritsky & Hughes, 1996). Furthermore, general instructional procedures, such as handing out an instructor-prepared outline of a lecture, are not adequate for many of these students (Ruhl & Suritsky, 1995).

ELL Students

As a group, students from linguistically and culturally diverse groups have higher school dropout rates and lower achievement test scores in all academic areas, including the sciences (Siegel, 2002). Although ELL students may have conversational English skills, they may not be proficient in using academic English (Crowther, Vila, & Fathman, 2006). It is desirable for ELL students to develop English skills in the context of the STEM instruction. An important process in facilitating acquisition of English skills in STEM courses is to provide students multiple formats for processing the material because this practice helps ensure that the students understand it (Crowther et al., 2006; Lee, 2005). These students may benefit from C-Print notes because they may provide a format that enables students to process the material at an understandable pace.

A study of 14 ELL high school students who were children of migrant workers points to the potential significance of distribution of detailed notes to promote student learning in this group. Students used networked laptop computers that permitted viewing of typed notes produced by note takers in a variety of courses. This project used Aspects collaborating writing software, not C-Print, to provide notes. After class, students received hard copies of the typed notes produced in both English and Spanish. Students' average grade in classes (many were STEM courses) with note taking support was one letter grade higher than for classes without the note taking support (Knox & Anderson-Inman, 2001).

Students Without an Identified Disability

Hearing students typically take their own notes during lectures, particularly in secondary and postsecondary education. Two major benefits of students taking their own notes have been the building of connections between new and previous knowledge and recording of class information for later study (Armbruster, 2000; Kierwa et al., 1991). After reviewing 25 years of research on note taking, Armbruster (2000) concluded that the primary use of students taking their own notes appeared to be the recording component. Instructors often use handouts, such as outlines, which are usually distributed to students for use during class. Research with students without an identified disability indicates that these materials can facilitate some types of learning, although results have been mixed. Armbruster (2000) concluded that little is understood regarding the benefits of handouts. Although the focus of much of the above discussion has been on students who are D/HH, those with a learning disability, and those who are ELLs, C-Print notes may also be beneficial for students without an identified disability who are more proficient users of English.

Purpose

This study compared the extent to which four different groups, (a) students who are D/HH, (b) those with learning disabilities, (c) those who are ELLs, and (d) those without an identified disability, benefitted from C-Print notes for STEM lectures. Postsecondary classes, including those in STEM, often contain diverse groups that include the four groups participating in the study. The study compared learning from study of the notes by each of the four groups to determine the relative potential of the notes as an accommodation to facilitate learning from STEM lectures. If one of these groups, such as those who are D/HH, did not show the same rate of gain as the other groups, this would suggest that additional steps, such as tutoring, might be needed to support their postclassroom learning of the material. Measuring the increase in performance from pre- to posttest for each of the four groups after study of the C-Print notes provided an assessment of learning. As discussed above, each of three of these groups, D/HH, ELL, and learning disability, has a different combination of factors (e.g., academic, cognitive) that may hinder comprehension of STEM lectures presented in spoken English. Students without an identified disability may benefit from these notes because learning from lectures in STEM courses is often difficult.

Students were given C-Print notes to study without prior hearing and viewing of the lecture in order to assess the independent contribution of the notes. In the normal processes of listening to and viewing a lecture, taking notes, and then reviewing them, the review of the notes is an important part of the process. Kobayashi (2006) found in a meta-analytic review of studies of students without a disability that the review function had a substantially greater effect on retention of lecture information (large to medium effect size 0.77) than did the note taking during the lecture function (small to medium effect size 0.22). The review of notes becomes increasingly important to retention the longer the time after the lecture that the test occurs. In addition, students' review of notes taken by others enhances learning from a lecture (Armbruster, 2000; Kiewra, 1985).

Because the review of notes is so important, investigation of notes by themselves without also including the lecture may be informative in certain circumstances. One such circumstance is when a study compares effects of notes taken by others upon several groups, as this study did. Although students do not normally only study notes, not including the lecture would isolate the effect of the notes themselves so that differential learning of the lecture content by each group while hearing and watching the lecture does not influence learning from study of the notes. Research does indicate that D/HH and ELL groups learn less from lectures than do students without a disability (Dunkel, Mishra, & Berliner, 1989;Marschark et al., 2005, 2006). In addition, D/HH students normally comprehend a lecture with a different form of presentation (sign language interpreter or real-time captioning) than do hearing students. Comprehension of the lecture with one of these accommodations may differentially affect learning from the notes.

Although D/HH students do use C-Print as a support during class, students with a learning disability, ELLs, and students without an identified disability are more likely to only receive a copy of notes. All students studied the notes for a short physics and a short biology lecture in order to assess the extent the notes facilitated learning in two different content areas.

In addition, the study included a qualitative examination of students' written comments about the C-Print notes in order to identify students' perceptions of what was desirable and undesirable about them, information that might help with interpretation of the quantitative results as well as yield suggestions for improving the notes.

Method

Participants

Participants were 100 undergraduate and graduate student volunteers in four groups enrolled at a large technical university in the northeastern United States: students were D/HH (n = 25); with a learning disability (n = 25); ELLs (n = 25); or without an identified disability (n = 25). The 25 D/HH students were recruited through a college for D/HH students at the technical university; the 25 students with a learning disability were recruited from the campus office for disability services; and the 25 ELL students were recruited through the university's English Learning Center. The 25 students without an identified disability were screened by questionnaire and recruiting material. A questionnaire administered during the experiment and the university's student databases provided information on student background. Tables 1–3 present data from students' responses to questionnaire items. (The Measures section describes the questionnaire.) Table 1 shows the distribution of student majors within colleges for the four groups of participants.

Table 2 presents the distribution of year in school for the four groups of participants.

Table 3 presents the distribution of science background for the participants.

As indicated by questionnaire responses, the students were enrolled in a variety of majors, primarily technical, were at various points in their academic careers, and had varying backgrounds in STEM. With few exceptions, most of the student participants were similar in their backgrounds. Half of the students in the D/HH group were enrolled in associates degree programs (many of these students eventually transfer to bachelors degree programs). All students in the other groups were enrolled in bachelors degree programs. D/HH students had completed fewer high school physics classes on average than students in the other groups. D/HH and ELL students had taken fewer college physics courses than students with a learning disability and those without an indentified disability.

English proficiency was assessed with the Scholastic Aptitude Test verbal section (College Board, 2012), the ACT reading test (ACT, 2011), and the Test of English as a Foreign Language (TOEFL) (ETS, 2011). Table 4 displays the mean scores on these tests for each group for whom at least two students completed the test. Students with a learning disability and those without an identified disability had higher percentile equivalent scores on these tests that did D/HH and ELL students. (The

Table 1 College enrollment by group of participants

	Deaf/hard of hearing (D/HH) (n = 25)	Learning disability (n = 25)	English language learners (n = 25)	No identified disability (n = 25)	$\chi^2(df = 3)$
Applied Science & Technology	1	7	5	4	5.64
Business	2	1	6	0	9.96*
Computer & Information Science	5	4	3	4	0.60
Engineering	2	2	5	8	6.80
Imaging Arts & Science	1	6	4	5	4.39
Liberal Arts	1	2	1	0	2.19
College for D/HH students (associates degree programs)	12 (Applied Computer Technology = 8; Business Studies = 1; Information Computer Studies = 3)	0	0	0	40.42**
Science	0	2	1	3	3.57
Undecided	1	0	0	1	2.00

Note. *$p < .05$, **$p < .01$.

Table 2 Year in school by group of participants

	Deaf/hard of hearing (n = 25)	Learning disability (n = 25)	English language learners (n = 25)	No identified disability (n = 25)	$\chi^2(df = 3)$
First	7	8	8	3	3.71
Second	9	3	1	8	10.53*
Third	4	3	0	2	4.32
Fourth	1	4	1	4	4.00
Fifth	1	2	0	0	3.78
Graduate school	3	5	11	8	7.46

Note. *$p < .01$.

Table 3 Science background by group of participants

	Deaf/hard of hearing (n = 25)	Learning disability (n = 25)	English language learners (n = 25)	No identified disability (n = 25)	$\chi^2(df = 3)$
High school biology	25	22	19	24	9.33*
College biology	5	7	2	5	3.31
High school chemistry	18	23	20	23	5.54
College chemistry	3	12	5	12	12.13**
High school earth science	19	17	11	13	6.67
College earth science	2	4	2	1	2.32
High school physics	10	22	21	17	16.95**
College physics	5	14	8	16	12.85**
High school math	24	24	23	24	0.63
College math	17	22	11	19	12.11**

Note. *$p < .05$, **$p < .01$.

Table 4 Mean scores on the Scholastic Aptitude Test (SAT) verbal section, the American College Testing (ACT) reading test and the Test of English as a Foreign Language (TOEFL) for each group for whom at least two students completed the test

	Test								
	SAT			ACT			TOEFL		
Group	M (SD)	Perc. eqv.[a]	n	M (SD)	Perc. eqv.[a]	n	M (SD)	Perc. eqv.[a]	n
Deaf/hard of hearing	417 (49.2)	20	7[b]	18.2 (5.6)	35	17	—[c]	—	—
Learning disability	562.8 (99.3)	67	18	24.3 (7.3)	70	6	—	—	—
English language learner	396.7 (126.6)	13	3	—	—	—	415 (184.5)	6	6
No identified disability	572 (74.3)	69	16	26.5 (4.9)	79	2	—	—	—

Note. [a]Percentile equivalent.
[b]*n*s reflect limited data available in school records.
[c]Not applicable.

English proficiency data were obtained from the university's student record system and consisted primarily of admission test scores. *N*s reflected the limited data available in school records. This limitation reflected the university's practice of not always requiring completion of an admission test, or in the case of ELL students not requiring completion of the TOEFL.) All of the D/HH participants had a severe–profound hearing loss.

Materials

For each subject (marine biology and physics), there was a set of materials including a pretest, notes developed with the tablet PC and C-Print software, and a posttest. To produce the C-Print notes for study, one faculty member each in the university's physics and biology departments delivered introductory lectures similar to those that they gave in their classes, except that they were shorter, approximately 15 min in length. These lectures included five to seven illustrative PowerPoint slides. The two faculty delivered their lectures in an outside-of-class session to ensure that the material was introductory, did not require a previous course session to be understood, had enough content to create pre- and posttests with sufficient items, and were similar in length. When the faculty presented their lectures, a C-Print service provider at the university who was experienced in providing C-Print services in the content area of the lecture produced text on a tablet PC and added graphics in a separate pane as appropriate, such as PowerPoint slides with a diagram.

To produce these notes, the provider used the C-Print Pro Tablet software application that supported a combined text and graphic representation of the lecture. As the faculty member talked, the provider typed a series of abbreviations. For each abbreviation typed, the software produced the equivalent full word on the computer screen (NTID, 2003). The software also enabled the provider to insert PowerPoint slides and to add highlighting, notations (including use of color), etc. to these materials. (The inclusion of the provider's notations, graphics, etc. required use of a tablet PC that accepted electronic stylus input in contrast to a standard laptop.) The C-Print notes being investigated in the study were a research prototype development and were not available for student use before or during the study in campus courses served by C-Print services.

After completion of each lecture, the provider saved the file and edited the notes in a manner similar to that in the normal provision of services, including insertion of graphical images next to the pertinent text. The text was in complete sentences, paragraphs showed changes in ideas, and the text was edited to correct for typing errors. The marine biology notes were four single-spaced pages (1,521 words) and the physics notes were four and half pages (1,706 words). Text was in black; graphics and annotations were in color. Readability was assessed using Flesch–Kincaid reading grade levels (Kincaid, Fishburn, Rogers, & Chissom, 1975) with Microsoft Word software. Reading grade levels were 4.7 for the physics lecture and 5.0 for the marine biology one. Figure 1 shows page one of the four pages for the marine biology notes.

Measures

Pre- and posttests for each topic were created by the lecturer. The marine biology posttest had 10 multiple-choice questions and the physics tests had eight multiple-choice and two short-answer questions. The pretest for each topic consisted of five randomly selected items from the posttest. The pre- and posttests are in Appendix A. All test items were scored as correct or incorrect based on an answer key provided by the lecturer. The two short-answer physics questions required students to sketch a motion diagram, such as one of a car moving in a constant speed. The physics lecture notes included the diagrams that were the answers to these questions, and a student's answer was scored as correct or incorrect in terms of whether it was similar to the diagram in the notes. For the diagram of a car moving in a constant speed to be scored as correct, the sketch had to show objects, such as dots, approximately equidistant from each other.

It was assumed that both the shorter pretests, which had half of the items contained in the posttests, as well as the posttests, would measure knowledge of the content that notes presented. A longer posttest was used in order to more completely assess knowledge of this content. This approach was taken in order to help keep the length of experimental sessions to 90 min, including the tests and study of notes. Students also completed a brief questionnaire that asked about the student's year in school, their major, and the number of science classes completed in high school and college. In addition, an open-ended item asked students to comment on the C-Print notes. Appendix B contains these items. In analyzing the comments, one researcher read through all the comments and identified major themes. A second researcher read the comments, reviewed the categories, and the two researchers agreed on modifications in categories. Next, one researcher developed a summary that integrated the comments and the second researcher read and modified this summary.

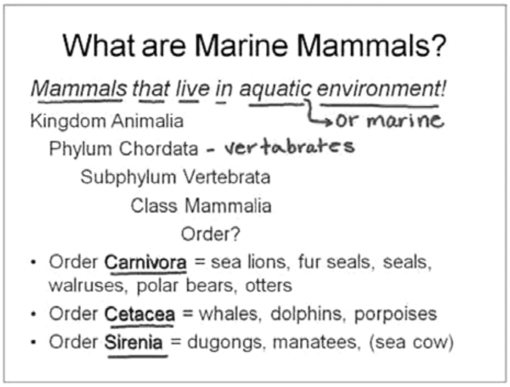
Procedure

Students participated in the study in groups of one to four students. At the start of the session, the researcher gave a short introduction to the procedure and students completed informed consent forms. Next, students received the pretest for the first subject and received up to 5 min to complete the test. Students turned in the pretest, and then received the C-Print notes to study for up to 25 min. Study tools such as blank paper, sticky notes, highlighters, and pens were available to the students; students were instructed to use these tools as they normally would to study class materials. When students finished studying, notes (and additional papers, if appropriate) were collected. The students then received the posttest and were allowed up to 10 min to complete

C-PRINT NOTES

Marine Biology **Professor Stelle**

Professor: Good afternoon! Today we will talk about **marine mammals**. This is an area I do research in so it is a favorite topic for me to discuss.

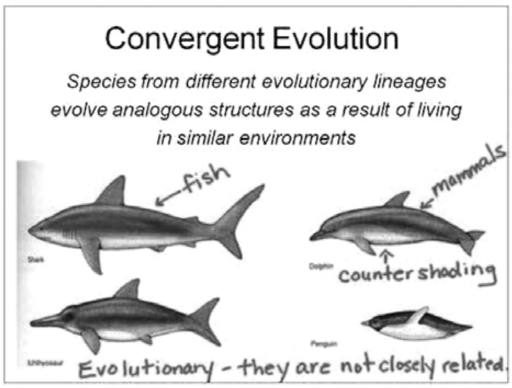


People ask what marine mammal means. It is a general description for mammals that rely on the **marine environment**. It includes whales and polar bears, who don't spend all their time in the ocean, but they feed on organisms there. They are still classified as marine mammals. They are all vertebrates, belonging to **phylum vertebrata**. They all belong to one class.

That is pretty much where the commonality ends. They are all mammals, but belong to different **orders** in that group. There is not a common phylogenetic relationship. We have **Carnivora**, including sea lions and walruses. Recently they decided to group them with other carnivores. We have two other groups, the **Cetacea** and **Sirenians**.

We have those 3 different orders that marine mammals belong to. Some people think it is very hard to combine them because evolutionarily they are not common.

Convergent evolution is when you have animals that live in a similar habitat but don't have a similar history. That strong habitat leads to similar body features and behaviors and lifestyles.



Here is an example of that. We have a shark, a dolphin, and an **ichthyosaur**, which is an ancient reptile now extinct, and a penguin. They have the **streamlined body shape** in common. They have a **counter shading** with dark on the back, light on the belly. That is good camouflage. The dark back blends in with the sea from above. From below the light belly blends in with the surface light.

For a long time people thought dolphins were fish. Then they realized they were air breathing and gave birth to live young, so they were mammals. You have to be careful when grouping animals together. Evolutionary these are not that closely related. A sea lion is not closely related to a dolphin. They just have similar habitats. But people often study both groups together due to the similar habitat.

I study whales and sea otters, I use a comparative approach.

Figure 1 Page one from C-Print notes for marine biology lecture. Notes provided courtesy of the Rochester Institute of Technology.

the posttest. At the conclusion of the test–study–test cycle for the first subject, the procedure was repeated for the second subject. Marine biology and physics materials were counterbalanced across students.

After completion of the second posttest, students completed the questionnaire and wrote out their comments about the C-Print notes.

Results

Performance on Marine Biology and Physics Tests

Students' percent correct scores on the marine biology and physics tests were analyzed to determine the effects of two factors: Group (four levels: D/HH, learning disability, ELL, and no disability) and Test (two levels: pre- and posttest, a within-subject's factor). (To adjust for the fact that the pretests had 5 items and the posttests had 10 items, for each student, the number correct for each pretest was divided by 5, and the number correct for each posttest was divided by 10, resulting in percent correct scores that could range from 0.00 to 1.00 for each test.) Table 5 presents mean pre- and posttest scores for the marine biology and physics tests as a function of participant group. Separate analyses were conducted for the marine biology and physics data. For each of these analyses, a mixed-design analysis of variance was performed on the dependent variable of percentage of items correct.

For marine biology, there was a statistically significant effect for Group, $F(3,96) = 5.29$, $p < .01$. To determine which group's performance was reliably different from that of the other groups, follow-up Tukey honestly significant difference (HSD) post hoc tests were conducted. These tests examined one score consisting of the combined mean for the pre- and posttest scores for each group. For each comparison, alpha was set at 0.05 and cell sizes for all groups were equal ($n = 25$). These analyses revealed that the combined mean for the learning disability group ($M = 0.52$) and that for the no identified disability group ($M = 0.53$) were higher than the mean for the D/HH group ($M = 0.39$). The differences between the mean for the ELL group ($M = 0.44$) and those for the other groups (learning disability, no disability, D/HH) were not statistically significant. The differences between the means for the learning disability and the no disability groups were also not significant.

The effect of Test was also significant, $F(1,96) = 96.8$, $p < .001$. For all students, the mean posttest score (0.60) was higher than the mean pretest score (0.34). The difference between these two scores indicated a 26% pre- to posttest gain in performance. Furthermore, the posttest mean was higher than the pretest one for each of the four groups.

The Group × Test interaction was not statistically significant. Inspection of means indicated that the differences between pre- and posttest scores for each group were not large enough to result in a significant interaction effect. (Differences ranged from 0.17 for D/HH to 0.33 for students with a learning disability.)

In the analyses of the physics data, the effect of Group was again significant, $F(3,96) = 15.50$, $p < .001$. Follow-up comparisons of the combined mean for the pre- and posttest scores with the Tukey HSD test

Table 5 Mean pre- and posttest scores for the marine biology and physics lecture notes as a function of participant group

	Test content and type							
	Marine biology				Physics			
	Pretest		Posttest		Pretest		Posttest	
Group[a]	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Deaf/hard of hearing	0.30	0.21	0.47	0.22	0.25	0.22	0.64	0.19
Learning disability	0.36	0.18	0.69	0.19	0.46	0.20	0.84	0.12
English language learner	0.34	0.22	0.54	0.16	0.38	0.19	0.78	0.13
No identified disability	0.38	0.25	0.70	0.16	0.53	0.18	0.83	0.12

Note. [a]n for each group = 25.

revealed that the learning disability ($M = 0.65$), no disability ($M = 0.68$), and ELL ($M = 0.58$) groups each had a significantly higher combined mean score than the D/HH group ($M = 0.45$). Differences between means for the learning disability, no disability, and ELL groups were not statistically significant.

The effect of Test was also again significant, $F(1,96) = 275.10$, $p < .001$, with the mean posttest score (0.78) higher than the mean pretest one (0.40). The difference between these two scores indicated a 38% gain in pre- to posttest performance. The average pre- to posttest gain for both the marine biology and physics notes was 32%. The Group × Test interaction was again not statistically significant. Pre- to posttest gains ranged from 0.30 for the no disability group to 0.41 for the ELL one.

Because each of the 10-item posttests in the above analyses included five items not in the pretest, a supplementary series of analyses was conducted to determine if results were identical if the pre- and posttests in a pair only had the same five items; that is, the items in the posttest not in the pretest were not included in these analyses. The results for these analyses were virtually identical to those for the analyses with the 10-item posttests. All statistical tests that had been significant with the 10-item posttests were also significant with the 5-item posttests, and all tests that were not significant with the 10-item posttests were also not significant with the 5-item posttests. For analyses with the 5-item posttests, the pre- to posttest gain in performance was 28% for the marine biology notes, 2% points higher than with the 10-item posttest, and 42% for the physics notes, four points higher.

Students' Comments About the C-Print Notes

In responding to a single open-ended question that asked students to write a short statement about the notes, students wrote about the note's graphics, the relationship between the text and the graphics, and the usefulness of the notes. Eighty-seven out of the 100 students provided these statements, which ranged from 1 to 121 words in length. Typically, students wrote a statement that the research team coded as a single "comment" or idea, which was either positive or negative; a few students, however, made both a positive and a negative comment. Overall, students made 65 positive comments about the notes; in addition, students made 43 comments about limitations.

Students in each of the four groups commented how the colored PowerPoint slides and diagrams contributed favorably to the appearance of the notes and were beneficial. The number of comments in a group ranged from three to eight. Among these comments were ones that stated that the graphics were "clear," which seemed to mean neat and understandable, and that annotations inserted in the PowerPoint slides, handwritten in color, were helpful. Other comments stated that the notes aided understanding and were motivating. The graphics provided a visual image that enabled students to better understand the material than reading the text alone. Students also stated that the graphics helped them identify important information. A D/HH student described the graphics' appearance and how they contributed to understanding:

> Notes look much clear compared to older version, pictures and diagrams helped me to identify major points.

This comment included comparison between this tablet version of the notes and the one typically used to provide C-Print services that had only text. (Most of the D/HH students were familiar with the standard C-Print service provided on the university's campus. In contrast, the other three groups of students tended to be unfamiliar with C-Print notes.) Three comments stated that the notes had beneficial motivational qualities. One student without an identified disability wrote:

> The dynamic of having any in-class visuals (powerpoint, etc) and a script for the lecture is engaging and a powerful study tool.

Students also commented on the combination of graphics and text, the colored annotations, and the use of bolding. Ten of the comments described the combination of graphics and text as providing comprehensive information about the lecture. One student with a learning disability wrote:

> They were very helpful and easy to follow. Having both the printed word and the diagrams made it almost as if you were sitting in a lecture.

Colored annotations in the text and in the graphics, as well as bolding in the text, were also beneficial because they helped students identify what was important and helped make the notes more interesting to study.

Nineteen student comments described how the notes were useful in more general ways. The notes contained detailed information that enabled students to acquire more knowledge about the lecture through independent study and review. Furthermore, the notes were useful to hearing students, not just those who were D/HH. One student with a learning disability described this general applicability:

> These are extremely valuable resource not only for deaf but for ADHD and dyslexics.

Thirty-three student comments described one of two limitations in the notes: (a) sections of text did not clearly reference the relevant graphic and (b) the graphics should have been bigger and/or clearer. With respect to the matching of particular sections of text with the relevant graphic, a student with a learning disability wrote:

> It was a little confusing trying to match up what was spoken with specific parts of the diagrams.

One student commented that he had not realized that the text referred to the adjacent image. Each graphic was adjacent to the section of the text to which it pertained; however, the graphic was not labeled with a figure number, etc., and the corresponding section of the text did not explicitly state that it referred to a specific figure. Student comments on confusion about the graphic–text correspondence may have reflected the absence of this link.

Four comments pertained to a desire for larger graphics for reasons such as students being able to add their own markings to the graphics while studying and being able to more easily focus on a part of a graphic. One comment by a student without an identified disability stated that written annotations on the PowerPoint slides were difficult to comprehend:

> Pictures were almost too busy. There was a lot of stuff crammed in together—that makes it harder to read and go through quickly.

Discussion

The major goal of the study was to compare the extent that each of four groups learned from studying C-Print notes with graphics. For each of the two content areas, participants showed a gain from pre- to posttest, with this gain averaging 32% for the two sets of notes. These findings suggest that the participants comprehended and remembered new material as a result of studying the notes. Because the results were similar for two content areas, the findings are presumably more reliable and have greater generality than if the study had only examined one content area.

Although the four groups did vary in the extent of gain from pre- to posttest for the two lectures, the variation in gain was not sufficiently large to suggest that any one group could not learn material when presented in this format. The absence of interaction effects for the four groups for both the physics and biology notes suggests that, in general, the four groups learned proportionally similar amounts of material in studying the notes. Students without an identified disability had the highest posttest scores, and they also had the highest pretest scores; furthermore, although the D/HH students had the lowest posttest scores, they also had the lowest pretest scores. In addition, for the two lectures, the groups with the largest and smallest pre- to posttest gains were not the same. For the marine biology lecture, the students with a learning disability had the largest gain and the D/HH students had the smallest. For the physics lecture, the ELLs had the largest gain and the students with no identified disability had the smallest.

It is not clear whether review of the C-Print notes will facilitate performance on tasks that involve higher order levels of learning because the test items used in the present study were recognition ones except for two recall items. Previous research on note taking typically has not found effects of review of notes upon these higher order levels of learning and this suggests that the same restriction in benefit for learning may occur for review of C-Print notes (Armbruster, 2000).

These results are initial evidence that suggests that the C-Print tablet notes with special graphics have the potential to support each of these four groups of students. This potential to support learning is important because all students, including those who are D/HH, ELL, or with a learning disability, have difficulty taking notes during class and effectively constructing new learning, although for different reasons (Crowther et al., 2006; Elliot et al., 2002; Hughes and Suritsky, 1993). Note taking during a lecture imposes considerable demand on the note taker because the speed of writing is about 10 times slower than that of speaking and because generating notes involves significant reorganization of the material while continuously following and remembering the lecture (Poliat, Olive, & Kellog, 2005). This continuous comprehension, reorganization, and retention of material, while simultaneously writing out notes, impose a substantial cognitive load on the note taker. Poliat et al. (2005) reviewed six studies that assessed the cognitive load of 12 different tasks for individuals without an identified disability and categorized these tasks into six levels of cognitive effort. They concluded that the cognitive load of note taking from a lecture was at the fifth most difficult level, slightly more difficult than experts playing chess and slightly less difficult than undergraduates composing a text. For students who have difficulty comprehending spoken English, such as D/HH students, comprehending a STEM lecture and taking notes at the same time can be a near impossible task if the expectation is that the student be actively engaged in the class presentation as well as taking full notes that are sufficient for future review. In support of this proposition, Faraco, Barbier, and Piolat (2002) found that French students with normal hearing showed greater cognitive effort in taking notes from a lecture in English, their second language, than taking them in French.

Students' comments identified features in the notes that may have contributed to the increased performance on the posttest. Neat, colored graphics consisting of PowerPoint slides with written annotations that were adjacent to pertinent text, along with selective bolding of text, may have aided understanding and facilitated identification of important information, as well as being interesting and attractive enough to motivate study. In addition, the extensive, detailed information in the notes, in contrast to an outline or brief sketch often characteristic of handwritten notes, may have also contributed to comprehension and retention of information.

The finding that students acquired substantial information from review of notes is consistent with previous studies of note taking that point to the importance of notes, including those taken by others, in providing material for review (Armbruster, 2000). This proposition means that notes such as the ones used are also likely to be useful students without an identified disability.

Although the study's findings provide some evidence in support of the potential of C-Print notes as a support in classrooms, more evidence is needed. An important follow-up study with these groups is needed to demonstrate that these notes contribute to learning when presentation of a lecture precedes study of the C-Print notes for that lecture. If the notes are truly beneficial, the four different groups should still be able to learn proportionately similar amounts of content from study of the notes in this situation.

In addition, it is not yet clear whether the tablet C-Print notes handouts are more beneficial than other forms of handouts for the various groups. Approaches to aid lecture comprehension that have been used with students without a disability have included handouts from instructors, outlines, and matrices of concepts to help students learn from lectures (Armbruster, 2000). The primary conclusion from these studies is that handouts are helpful, but it is not clear what form is most effective (Armbruster, 2000). This conclusion was based only on the studies that included comparison of handout review and no review conditions. A handout that has been used with students with a learning disability is a lecturer provided outline (Ruhl & Suritsky, 1995). With D/HH students, written notes generally in outline format, C-Print notes without graphics, and stenographic-based verbatim transcripts have been provided (Marschark et al., 2006; Osgurthorpe, Long, & Ellsworth, 1980; Stinson et al., 2009). Thus, another area in which research is needed is to compare the effects of review of various types of notes (e.g., text only, handwritten produced by a note taker, as well as notes such as those used in the present study that combine text and graphics).

Courses in STEM fields have traditionally been perceived as difficult, given the complexity of the material and the requirements of STEM related professions. This difficulty and these perceptions are associated with reduced enrollment in STEM majors and a 40% attrition rate, a higher rate than for non-STEM majors (Daempfle, 2003; Seymour & Hewitt, 1997). In recent years, STEM educators have increasingly explored new approaches to providing STEM instruction in order to make education in these fields more accessible to all students and to provide a greater focus on student learning (Bransford, Brown, & Cocking, 2000; Seymour, 2001).

In this context, although there is a need for more evidence, the present study's findings suggest that STEM educators consider distribution of the C-Print notes to all students in their classes. The cost of C-Print services, $15–35 per hour (which is primarily for the service provider), makes it a feasible service to include in many courses. When C-Print services are provided as an accommodation for a student with a disability, such as a D/HH student, the institution covers cost of the service. Instructors can take advantage of this provision of services to students with disabilities and request distribution of notes to all registered students at minimal cost. If instructor experience and research indicate that distribution of the notes is an appropriate teaching/learning tool, C-Print services may also be provided in selected courses so that all students receive C-Print notes, especially in those courses that students have difficulty completing, even when there is not a D/HH student. When C-Print notes are distributed to all students, C-Print becomes more than an accommodation to provide communication access to D/HH students. Distribution of notes to all students makes the service consistent with principles of universal design for instruction that emphasize the desirability of instructional approaches that facilitate learning by students with diverse characteristics, including those who are proficient academically (Hitchcock & Stahl, 2003).

Although this study involved students studying notes based on the STEM content areas of physics and marine biology, the C-Print notes with graphics may also be helpful in any content area where teachers simultaneously present information in multiple forms (e.g., speech and PowerPoint slides). For example, the special C-Print notes may be an effective support in business classes with a quantitative emphasis. Furthermore, these notes may be useful to students in high school and middle school as well as at the postsecondary level.

There was a significant Group effect, and therefore follow-up tests that compared the overall performance of the groups with each other were conducted, even though these differences were not the primary focus of the study. (These group differences pertained to the average of the pre- and posttest scores, not the gain from pre- to posttest, which was the primary focus of the study.) Results of the follow-up tests indicated that D/HH participants consistently scored lower on these average scores than the other participants. It is possible that differences between the D/HH students' and other students' science backgrounds, as indicated by D/HH students reporting that they completed fewer high school and college physics courses than did the other groups, related to the differences between the D/HH and other groups' performance on the tests, particularly the physics ones. Previous studies have found that students without identified disabilities who have more background knowledge demonstrated greater comprehension of science text than students with less background (Cromley, Snyder-Hogan, & Luciw-Dubas, 2010; Ozuru, Dempsey, & McNamara, 2009; Tarchi, 2010). These studies used a topic-specific measure of background knowledge, such as knowledge about the digestive system, in contrast to the self-reports of science classes completed that were used in this study. Any relationship between such self-reports and comprehension of STEM material may be weaker than that for a topic-specific measure of prior knowledge.

In addition, the D/HH students' relatively lower proficiency in English could have contributed to these students' lower performance on the pre- and posttests (Marschark & Wauters, 2008; Mitchell & Karchmer, 2011). In this study, the D/HH and ELL students' scores on the measures of English proficiency (e.g., ACT reading test) were substantially lower than those of the students with a learning disability or without an identified disability. Consistent with this interpretation, Stinson et al. (2009) and Marschark et al. (2006) found that D/HH students' reading proficiency was related to retention after viewing a lecture with interpreting or captioning and also studying notes afterward. Cromley et al. (2010) and Ozuru et al. (2009) found that for college students without a disability, reading skills was related to comprehension of science texts, independent of prior knowledge.

In the present study, although the D/HH and ELL students' scores on the verbal subtests were relatively low, the ELL students performed somewhat better than the D/HH students on the pre- and posttests. One interpretation of this difference is that there were so few verbal test scores for the ELL students that the information was not reliable. Another interpretation is that differences between the D/HH and other groups in metacognitive abilities and in utilization of prior knowledge in acquiring new information affected performance (Borgna, Convertino, Marschark, Morrison, & Rizzolo, 2011; Marschark & Wauters, 2008). It should also be noted that both the D/HH group's mean posttest scores for the marine biology lecture was below 50%. This result may have occurred because the material was more verbal for the marine biology lecture than for the physics one. Despite D/HH students' lower performance on the tests in the present study, this group of students achieved pre- to the posttest gains that were comparable to those of the other groups.

One limitation of this study is that it did not allow for effective examination of relations between individual differences in reading proficiency and prior knowledge and learning from notes. Such an examination would shed additional light on the question of who can benefit from the C-Print notes for STEM lectures. One way this study did not allow for effective examination is that the sample sizes of 25 within each group meant that tests for statistical significance of relationships between individual difference variables would be underpowered. Second, it would be desirable for the measures of reading proficiency and prior knowledge to be more specific. Rather than using a general measure of verbal ability and self-reports of science knowledge, as were used in this study, it is desirable to use more specific measures of reading proficiency and of knowledge of the science area addressed by the notes.

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Conflicts of Interest

No conflicts of interest were reported.

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References

ACT. (2011). *2001 ACT National and State Scores*. Iowa City, IA: Author. Retrieved from http://www.act.org/news/data/01/t4.html

American Council on Education. (2001). *College freshmen with disabilities: A biennial statistical profile*. Washington, DC: Heath Resource Center, American Council on Education.

Al-Hilawani, Y. A. (1999). A comparison among average-achieving, underachieving, and deaf/hard-of-hearing students on effective study skills and habits. *International Journal of Special Education*, *14*, 12–24.

Armbruster, B. B. (2000). Taking notes from lectures. In R. Flippo & D. Caverly (Eds.), *Handbook of college reading and study strategy research* (pp. 175–199). Mahwah, NJ: Lawrence Erlbaum Associates.

Borgna, G., Convertino, C., Marschark, M., Morrison, C., & Rizzolo, K. (2011). Enhancing deaf students' learning from sign language and text: Metacognition, modality, and the effectiveness of content scaffolding. *Journal of Deaf Studies and Deaf Education*, *16*, 79–100. doi:10.1093/deafed/enq036

Bransford, J. D., Brown, A. L., & Cocking, R. R. (Eds.). (2000). *How people learn* (Expanded ed.). Washington, DC: National Academy Press.

Burns, E. (2003). Assistive technology. In L. C. Shea & S. W. Strothman (Eds.), *Understanding learning disabilities at the postsecondary level* (pp. 177–196). Putney, VT: Landmark College.

College Board. (2012). *Interpreting and using SAT scores*. New York, NY: Author. Retrieved from www.collegeboard.com%2Fprod_downloads%2Fcounselors%2Fhs%2Fsat%2Fresources%2Fhandbook%2F4_InterpretingScores.pdf

Cromley, J. G., Snyder-Hogan, L., & Luciw-Dubas, U. (2010). Reading comprehension of scientific text: A domain-specific test of the direct and inferential mediation model of reading comprehension. *Journal of Educational Psychology*, *102*, 687–700. doi:10.1037/a0019541

Crowther, D. T., Vila, J. S., & Fathman, A. K. (2006). Learners, programs, and teaching practices. In A. K. Fathman & D. T. Crowther (Eds.), *Science for English language learners* (pp. 9–24). Arlington, VA: National Science Teachers Association Press.

Daempfle, P. A. (2003). An analysis of the high attrition rates among first year college science, math, and engineering majors. *Journal of College Student Retention: Research, Theory and Practice*, *5*, 37–52. doi:10.2190/dwqt-tya4-t20w-rcwh

DiVesta, F. J., & Gray, S. G. (1972). Listening and note-taking. *Journal of Educational Psychology*, *63*, 8–14. doi:10.1037/h0032243

Dunkel, P., Mishra, S., & Berliner, D. (1989). Effects of note taking, memory, and language proficiency on lecture learning for native and nonnative speakers of English. *TESOL Quarterly*, *23*, 543–549. doi:10.2307/3586929

ETS. (2011). *Test and score data summary for TOEF Internet-based and paper-based tests*. Princeton, NJ: Author. Retrieved from www.ets.org/toefl

Elliot, L. B., Foster, S. B., & Stinson, M. S. (2002). Student study habits using notes from a speech-to-text support service. *Exceptional Children*, *69*, 25–40.

Faraco, M. Barbier, M., & Piolat, A. (2002) A comparison between notetaking in L1 and L2 by undergraduate students. In G. Rijlaarsdam, S. Ransdell, & M. Barfbier (Eds.), *Studies in writing. Vol. 11: New directions for research in L2 writing* (pp. 145–167). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Fathman, A. K., & Crowther, D. T. (2006). Teaching English through science and science through English. In A. K. Fathman & D. T. Crowther (Eds.), *Science for English language learners* (pp. 3–8). Arlington, VA: National Science Teachers Association Press.

Gardner, J. A. (2002). *Science educational information and students with print disabilities*. Corvallis, OR: Oregon State University. Retrieved from http://dots.physics.orst.edu/~gardner/ScienceEd.html

Hastings, D., Brecklin, K., Cermak, S., Reynolds, R., Rosen, H., & Wilson, J. (1997). *Note taking for deaf and hard of hearing students: A report of the National Task Force on Quality of Services in the Postsecondary Education of Deaf and Hard of Hearing Students (ERIC Document Reproduction Service No. ED 437 777)*. Rochester, NY: Northeast Technical Assistance Center, Rochester Institute of Technology.

Heiman, T., & Precel, K. (2003). Students with learning disabilities in higher education: Academic strategies profile. *Journal of Learning Disabilities*, *36*, 248–258. doi:10.1177/002221940303600304

Hitchcock, C., & Stahl, S. (2003). Assistive technology, universal design, universal design for learning: Improved learning opportunities. *Journal of Special Education Technology*, *18*, 45–52.

Hughes, C. A., & Suritsky, S. K. (1993). Notetaking skills and strategies for students with learning disabilities. *Preventing School Failure*, *38*, 7–11.

Igo, L. B., Riccomini, P. J., Bruning, R. H., & Pope, G. G. (2006). How should middle-school students with LD approach online notetaking? A mixed-methods study. *Learning Disability Quarterly*, *29*, 89–100.

Kiewra, K. A. (1985). Providing instructor's notes: An effective addition to student note taking. *Educational Psychologist*, *20*, 33–39. doi:10.1207/s15326985ep2001 5

Kierwa, K. A., DuBois, N. F., Christian, D., McShane, A., Meyerhoffer, M., & Roskelley, D. (1991). Notetaking functions and techniques. *Journal of Educational Psychology*, *83*, 240–245.

Kincaid, J. P., Fishburn, R. P., Rogers, R. L., & Chissom, B. S. (1975). *Derivation of new readability formulas for Navy enlisted personnel (Research Branch Report 8-75)*. Millington, TN: Naval Air Station Memphis.

Knox, C., & Anderson-Inman, L. (2001). Migrant high school students succeed using networked laptops. *Learning and Leading with Technology*, *28*, 18–53.

Kobayashi, K. (2006). Combined effects of note-taking/-reviewing on learning and the enhancement through interventions: A meta-analytic review. *Educational Psychology*, *26*, 459–477. doi:10.1080/01443410500342070.

Lee, O. (2005). Science education with English language learners: Synthesis and research agenda. *Review of Educational Research*, *75*, 491–530. doi:10.3102/00346543075004491

Marschark, M., Leigh, G., Sapere, P., Burnham, D., Convertino, C., Stinson, M., … Grebennikov, L. (2006). Benefits of sign language interpreting and text alternatives for deaf students' classroom learning. *Journal of Deaf Studies and Deaf Education*, *11*, 421–437. doi:10.1093/deafed/enl013

Marschark, M., Sapere, P., Convertino, C., & Seewagen, R. (2005). Educational interpreting: Access and outcomes. In M. Marschark, R. Peterson, & E. Winston (Eds.), *Sign language interpreting and interpreter education: Directions for research and practice* (pp. 76–95). New York, NY: Oxford University Press.

Marschark, M., & Wauters, L. (2008). Language comprehension and learning by deaf students. In M. Marschark & P. Hauser (Eds.), *Deaf cognition* (pp. 309–350). New York, NY: Oxford University Press.

Mayer, R. E. (2001). *Multimedia learning*. New York, NY: Cambridge University Press.

Mitchell, R. E., & Karchmer, M. A. (2011). Demographic and achievement characteristics of deaf and hard-of-hearing children. In M. Marschark & P. Spencer (Eds.), *Oxford handbook of deaf studies, language, and education* (pp. 18–31). New York, NY: Oxford University Press.

National Technical Institute for the Deaf. (2003). *C-Print training (on-line instruction)*. Rochester, NY: Rochester Institute of Technology. Retrieved from http://www.ntid.edu/elearning/C-Print

National Technical Institute for the Deaf. (2006). *Science education for deaf and hard-of-hearing students website*. Rochester, NY: Rochester Institute of Technology. Retrieved from http://www.rit.edu/~comets/

Osgurthorpe, R., Long, G., & Ellsworth, R. (1980). The effects of reviewing class notes for deaf and hard of hearing students. *American Annals of the Deaf*, *125*, 554–558. doi:10.1353/aad.2012.1532

Ozuru, Y., Dempsey, K., & McNamara (2009). Prior knowledge, reading skills, and text cohesion in the comprehension of science texts. *Learning and Instruction*, *19*, 228–242. doi:10.1016/j.learninstruc.2008.04.003

Peper, R. J., & Mayer, R. E. (1986). Generative effects of note taking during science lectures. *Journal of Educational Psychology*, *78*, 34–38. doi:10.1037/0022-0663.78.1.34

Poliat, A., Olive, T., & Kellog, R. T. (2005). Cognitive effort during note taking. *Applied Cognitive Psychology*, *19*, 291–312. doi:10.1002/acp.1086

Richardson, J. T. E., MacLeod-Gallinger, J., McKee, B., & Long, G. (2000). Approaches to studying in deaf and hearing students in higher education. *Journal of Deaf Studies and Deaf Education*, *5*, 156–173. doi:10.1093/deafed/5.2.156

Ruhl, K. L., & Suritsky, S. (1995). The pause procedure and/or an outline: Effect on immediate free recall and lecture notes taken by college students with learning disabilities. *Learning Disability Quarterly*, *18*, 2–11.

Seymour, E. (2001). Tracking the processes of change in US undergraduate education in science, mathematics, engineering, and technology. *Journal of Science Education*, *86*, 79–105. doi:10.1002/sce.1044

Seymour, E., & Hewitt, N. M. (1997). *Talking about leaving: Why undergraduates leave the sciences*. Boulder, CO: Westview Press.

Siegel, H. (2002). Multiculturalism, universalism, and science education: In search of common ground. *Science Education*, *86*, 803–820. doi:10.1002/sce.1052

Simon, J. A. (1999). Postscript pertaining to laws and regulations. In R. Stuckless (Ed.), *Reports of the National Task Force on Quality Services in Postsecondary Education of Deaf and Hard of Hearing Students (ERIC Document Reproduction Service No. ED 441 296)* (pp. 18–19). Rochester, NY: Northeast Technical Assistance Center, Rochester Institute of Technology.

Smith-Pethybridge, V. (2005). *Improved retention and success in mathematics courses through SmartBoard technology*. Miami, FL: Miami-Dade College.

Stinson, M. S., Eisenberg, S., Horn, C., Larson, J., Levitt, H., & Stuckless, R. (1999). Real-time speech-to-text services. In R. Stuckless (Ed.), *Reports of the National Task Force on Quality Services in Postsecondary Education of Deaf and Hard of Hearing Students (ERIC Document Reproduction Service No. ED 441 296)* (pp. 1–23). Rochester, NY: Northeast Technical Assistance Center, Rochester Institute of Technology.

Stinson, M. S., Elliot, L. B., & Francis, P. (2008). The C-Print system: Using captions to support classroom communication access and learning by deaf and hard of hearing students. In C. Schlenker-Schulte & A. Weber (Eds.), *Barrieren überwinden—Teilhabe ist möglich! Villingen-Schwenningen* (pp. 102–122). Villingen-Schwenningen, Germany: Neckar-Verlag.

Stinson, M., Elliot, L., Kelly, R., & Liu, Y. (2009). Deaf and hard-of-hearing students' memory of lectures with speech-to-text and interpreting/note taking services. *Journal of Special Education*, *43*, 52–64. doi:10.1177/0022466907313453

Stinson, M. S., Elliot, L., McKee, B., & Francis, P. (2000). The C-Print real-time speech-to-text support service. *Volta Voices*, *8*, 16–22.

Strawser, S., & Miller, S. P. (2001). Math failure and learning disabilities in the postsecondary student population. *Topics in Language Disorders*, *21*, 68–84.

Suritsky, S. K., & Hughes, C. A. (1991). Benefits of notetaking: Implications for secondary and postsecondary students with learning disabilities. *Learning Disability Quarterly*, *14*, 7–18.

Suritsky, S. K., & Hughes, C. A. (1996). Notetaking strategy and instruction. In D. D. Deshler, E. S. Ellis, & B. K. Lenz (Eds.), *Teaching adolescents with learning disabilities* (pp. 267–312). Denver, CO: Love Publishing Company.

Tarchi, C. (2010). Reading comprehension of informative texts in secondary school: A focus on direct and indirect effects of reader's prior knowledge. *Learning and Individual Differences*, *20*, 415–420. doi:10.1016/j.indif.2010.04.002

Appendix A: Pre- and Post Tests

Introduction to Physics Pretest

1. The three fundamental concepts of physics are
   (a) matter, space, and energy
   (b) matter, time, and force
   (c) motion, matter, and space
   (d) matter, space, and time

2. The three fundamental Standard International (SI) units are
   (a) the kilogram, the centimeter, and the hour
   (b) the kilogram, the meter, and the second
   (c) the Newton, the second, and the meter
   (d) none of these

3. To describe motion, we need
   (a) a clock
   (b) a mass balance
   (c) a coordinate reference frame and a clock
   (d) none of these

4. The concept of velocity is the ratio of
   (a) displacement over time
   (b) position over time
   (c) distance over time
   (d) none of these

5. Sketch a "motion diagram" for a car moving with a constant speed in one dimension.

Introduction to Physics Posttest

1. The most general way to describe physics is as:
   (a) the study of force
   (b) a language
   (c) the study of energy
   (d) none of these

2. The three fundamental concepts of physics are
   (a) matter, space, and energy
   (b) matter, time, and force
   (c) motion, matter, and space
   (d) matter, space, and time

3. The three fundamental SI units are
   (a) the kilogram, the centimeter, and the hour
   (b) the kilogram, the meter, and the second
   (c) the Newton, the second, and the meter
   (d) none of these

4. The concept of time is most closely related to
   (a) the concept of force
   (b) the concept of matter
   (c) the concept of motion
   (d) none of these

5. To describe motion, we need
   (a) clock
   (b) a mass balance
   (c) a coordinate reference frame and a clock
   (d) none of these

6. The concept of displacement involves
   (a) the change of an objects position
   (b) the change of time during a collision
   (c) the change of distance traveled
   (d) none of these

7. The concept of velocity is the ratio of
   (a) displacement over time
   (b) position over time
   (c) distance over time
   (d) none of these

8. The concept of speed is
   (a) the magnitude of displacement
   (b) the magnitude of velocity
   (c) the magnitude of position
   (d) none of these

9. Sketch a "motion diagram" for a car moving with a constant speed in one dimension.

10. Sketch a motion diagram for a car slowing down in one dimension.

Marine Biology Pretest

1. Whales belong to the Order:
   (a) Carnivora
   (b) Cetacea
   (c) Sirenia
   (d) Mammalia

2. Both dolphins and sea lions have a streamlined body form; this is because:
   (a) they are both vertebrates
   (b) they share an evolutionary history
   (c) they evolved from pigs in the South Pacific
   (d) of convergent evolution

3. Which of the following features is NOT characteristic of seals?
   (a) worm-like movement on the ground
   (b) external earflaps
   (c) foreflippers with nails
   (d) hindflippers that trail behind the body

4. Which Order of marine mammals evolved most recently?
   (a) Cetaceans
   (b) Sirenians
   (c) Pinnipeds
   (d) they all evolved at the same time

5. What led to the evolution of marine mammals?
   (a) extinction of dinosaurs allowed mammals to diversify
   (b) some mammals returned to the sea to avoid land predators
   (c) some started to feed in the ocean to take advantage of unexploited sources
   (d) all of the above
   (e) none of the above

Marine Biology Posttest

1. Whales belong to the Order:
   (a) Carnivora
   (b) Cetacea
   (c) Sirenia
   (d) Mammalia

2. Which of the following animals belong to the same Order as sea lions and seals?
   (a) dolphins
   (b) dugongs
   (c) otters
   (d) manatees
   (e) none of the above

3. Both dolphins and sea lions have a streamlined body form; this is because:
   (a) they are both vertebrates
   (b) they share an evolutionary history
   (c) they evolved from pigs in the South Pacific
   (d) of convergent evolution

4. Manatees are most closely related to:
   (a) elephants
   (b) hippopotamus

(c) bears
(d) sheep

5. Which of the following features is NOT characteristic of seals?
   (a) worm-like movement on the ground
   (b) external earflaps
   (c) foreflippers with nails
   (d) hindflippers that trail behind the body
6. Which marine mammal is a vegetarian?
   (a) polar bears
   (b) porpoises
   (c) sea otters
   (d) dugongs
7. Which Order of marine mammals evolved most recently?
   (a) Cetaceans
   (b) Sirenians
   (c) Pinnipeds
   (d) they all evolved at the same time
8. Which animal filters plankton and small fish using baleen?
   (a) walrus
   (b) otariid
   (c) manatee
   (d) odontocete
   (e) mysticete
9. What led to the evolution of marine mammals?
   (a) extinction of dinosaurs allowed mammals to diversify
   (b) some mammals returned to the sea to avoid land predators
   (c) some started to feed in the ocean to take advantage of unexploited sources
   (d) all of the above
   (e) none of the above
10. You are a scientist working in an unexplored region of the Pacific and observe an animal that is streamlined, cannot leave the water, eats fish, and uses echolocation to find food and navigate. How would you classify this species?
    (a) Carnivora
    (b) Fur seal
    (c) Sirenian
    (d) Odontocete
    (e) Archaeoceti

Appendix B: Questionnaire Items

1. What is your year in school?
   First ___
   Second ___
   Third ___
   Fourth ___
   Graduate student ___
   Other—please specify:
   ____
2. How many science classes have you taken? (Write estimated number.)

	High School	College
Biology	___	___
Chemistry	___	___
Earth Science	___	___
Physics	___	___
Math	___	___

3. What is your major? ______________________
4. Comments about the C-Print notes:
   ____
   ____