Accuracy of Sign Interpreting and Real-Time Captioning of Science Videos for the Delivery of Instruction to Deaf Students

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The purpose of this study was to quantitatively examine the impact of third-party support service providers on the quality of science information available to deaf students in regular science classrooms. Three different videotapes that were developed by NASA for high school science classrooms were selected for the study, allowing for different concepts and vocabulary to be examined. The focus was on the accuracy of translation as measured by the number of key science words included in the transcripts (captions) or videos (interpreted).

Data were collected via transcripts completed by CART (computer assisted real-time captionists) or through videos of sign language interpreters. All participants were required to listen to and translate these NASA educational videos with no prior experience with this information so as not to influence their delivery.

CART personnel using captions were found to be significantly more accurate in the delivery of science words as compared to the sign language interpreters in this study.

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ACKNOWLEDGEMENTS

I am very thankful for all the people who made it possible for me to get to complete this phase of my educational journey. This isn't just about those who helped me through the dissertation process, but the many people who made it possible for me to even dream of a college education. I was not able to finish college the first time around due to lack of equal access and the laws providing such access motivated me not only to continue my education, but also to pursue such access as the focus of my doctoral dissertation study.

There were many interpreters who assisted me and who did phenomenal jobs in spite of difficult classes especially in neuroscience and science education.

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1.0 CHAPTER 1: INTRODUCTION TO THE STUDY

"…deafness entails a different educational perspective of the child-one that is grounded in the field of vision and wrapped around the linguistics of both ASL and English and the relationship of these two languages to each other."

(Pearls of Wisdom, David Stewart, 2002)

1.1 Background

"The present status of education for persons who are deaf in the United States, is unsatisfactory. Unacceptably so…"

(Commission on the Education of the Deaf, 1988)

The push for inclusion and the simultaneous drive for the use of technology in K-12 classrooms over the past 30 years has increased the options for communication of course content to learners with deafness in science classrooms. As a result of the passage of The Education for All Handicapped Children Act in 1975 (now known as the Individuals with Disabilities Education Act or IDEA), the mainstreaming movement gained significant momentum and shifted the placement of many students with deafness from residential schools to the public schools. This movement was in keeping with the changing national philosophy of equality, and the now widely-held belief that deaf students are just like hearing students (Gearhart, Mullen, & Gearhart, 1993; Seal, 1998). This mistaken concept has been refuted by other researchers in deaf education, who argue that deaf children “should not be taught as though they are hearing students who cannot hear” (Marschark, Lang, & Albertini, 2002, p. 134), and has led to policies that are not always in the best interest of the deaf student. The educational impact of mainstreaming deaf students in a regular classroom has not been extensively researched though it is known that 85% of all deaf or hard-of-hearing students are in public classrooms (U.S. Department of Education, Office of Special Education and Rehabilitative Services, & Office of Special Education Programs, 2004). With 43% of these students attending general education classrooms, it becomes imperative to determine the quality and the quantity of the delivery of subject matter in the classroom through the use of interpreters or real-time captioning such as Computer Aided Real-time Translation (CART). The accuracy of such delivery has not been adequately examined in the context of science education.

Before the passage of both the IDEA and Section 504 of the 1973 Rehabilitation Act that are currently the most used constitutional entitlements passed by Congress to specify and protect the educational rights of persons with disabilities, public schools were not considered appropriate environments for students with deafness like most other students with disabilities were considered uneducable in public schools (Yudof, Kirp, & Levin, 1992). Most deaf students were educated either in private residential schools or in day school programs separated from students with normal hearing. In many programs the emphasis was not placed on education, but rather on teaching speech and hearing skills to children with deafness. This stress often led to students with deafness leaving schools with a lack of education that would enable them to function successfully in society (Reed, Antia, and Kreimeyer, 2008).

However, with the passage of the IDEA, came a change in attitude that led to the socialization concept of placing deaf and hard-of-hearing students with their hearing peers. At first, these students were placed in the same schools but in separate classrooms. Educators also experimented with partial inclusion efforts where the students were placed in the same classrooms with hearing students for certain subjects. Currently, there is more emphasis on full inclusion with all students together in public schools (Ramsey, 1997). This inclusion movement has led some states to close residential schools for deaf students, and has in turn forced students who had been attending these schools to enroll in inclusion programs, regardless of whether the students were ready to be placed into classrooms with their hearing peers (Bloch, 2004; Stewart, 2002).

Deaf students placed in public schools need classroom support services. State education departments and school districts involved in developing Individualized Education Programs (IEPs) as required by law are responsible for *determining how* deaf students receive their educational information (Individuals with Disabilities Education Act, 1997). The IDEA requires ‘that all children with disabilities have available to them a free *appropriate* public education…designed to meet their needs (ibid).” The IDEA also ensures the provision of “related services and aids and supports in the regular classroom to such children, whenever *appropriate* (Section 601, Part 5).”

Public schools are required by law to assist deaf students through provision of interpreters and/or note takers. The two most commonly used support services for providing communication access in public school classrooms are interpreters and steno-based speech-to-text systems (Brennan-Dore, Davis, Trychin, & Rawlinson, 2001;

Stinson, Eisenberg, Horn, Larson, Levitt, & Stuckless, 1999; Virginia Department of Education, 1993; Ramsey, 1997).

As stated in the report *Real-Time Speech-to-Text Services* (Stinson, et al., 1999) steno-based services are being used for deaf students in many mainstream secondary and post-secondary environments. Importantly, current practices have provided no legal definitions of accuracy for providing information that is on par with the information received by normal hearing students. The lack of standards is problematic for both educational interpreting and educational steno-based reporting. Neither government regulations such as Section 504 of the 1973 Rehabilitation Act nor by private organizations such as the Registry of Interpreters for the Deaf (2004) have addressed this issue adequately. States and school districts are using available personnel in their areas for interpreting or steno-based systems, and are not making appropriate efforts to evaluate the quality of such services.

1.2 STATEMENT OF THE PROBLEM

This study will address the accuracy of two support service delivery systems for translating video material for deaf students in real-time in public school science classrooms. Specifically, the study will focus on the use of ASL interpreters and real-time captioning. These two formats for delivery of classroom information will be examined to compare the videotaped sign and printed forms of the stenographers' translations with the original spoken messages. The results of this comparison will be discussed in relationship to the service providers' content knowledge and training and in the technology available to the service provider as concerns dictionaries for CART. This study may shed light on the quality of information deaf and hard-of-hearing students are getting from their service providers, and whether the training of those service providers needs to be changed in order to make the information delivered more accurate.

The provision of accurate science information is imperative in this day and age for deaf students to obtain an education that leads to both employment and the ability to make informed choices throughout life. Science (and mathematics) courses contain challenging information to learn, and the communication of this information may be dependent upon the knowledge base and/or the training of the person conveying the information. Comprehension of science may be dependent upon teacher content knowledge. For deaf students, there is also the possibility that third-party support service providers may make science learning more difficult by introducing errors in translation of a teacher's message, or inadvertently leaving out critical information. In the case of real-time captioning, there may be technical problems related to the dictionaries installed in the computers (Stinson, et al., 1999). This study focuses on the accuracy of translations by third-party support service providers, interpreters and CART, when conveying science information to students with deafness.

1.2.1 Interpreters and American Sign Language in the Classroom

Deaf students, like students without disabilities, are an extremely heterogeneous population. In fact, they may be more heterogeneous in several areas than hearing students (Marschark, et al., 2002). Deaf learners *do not* all know American Sign Language (ASL), and those who do know ASL have often not been exposed to it consistently since birth. Mayberry stated "Historically, a majority of American deaf signers first acquired sign language in circumstances that were not analogous to the acquisition to a spoken language by children with normal Hearing. Many deaf signers first learned to sign at older ages in school dormitories and on playgrounds from deaf friends instead of in the nursery on the laps of their parents" (Mayberry, 1994, p. 62). Since most deaf children are born to hearing parents, the timing of and the emphasis on type of language will differ according to the flexibility and the motivation of the parents (Pressman, Pipp-Siegel, Yoshinaga-Itano, & Deas, 1999; Schein & Delk, 1974). Marschark, De Beni, Polazzo, and Cornoldi (1993) stated, "It is rare that deaf children are exposed *exclusively* to sign language" (p. 25). Many deaf students cannot speech-read[1] and those who can speech-read have difficulty doing so in the classroom environment when teachers turn to face blackboards, mumble, or have facial hair (Marschark, et al., 2002). Deaf students also vary in reading skills, due to their diverse and often late exposure to language. This will directly impact their ability to learn. Deaf students, not surprisingly, start school with a much smaller vocabulary then hearing students do and this in turn affects not only their ability to recognize text, but also their ability to recognize and use fingerspelling of their interpreters when novel words and concepts need to be fingerspelled because of lack of signs available especially within science, math, and technical vocabularies (Paul, 1996; Waters & Mayberry, 1987). Fingerspelling is the representation of letters in a writing system, whether it is English or another language.

There has been a vast change in attitude towards the use of sign language in public educational programs over the past 30 years. The pivotal works of William Stokoe & colleagues (Stokoe,1960; Stokoe, Casterline, & Croneberg, 1965), Bellugi and Klima (1972, 1979), and Helen Neville and her colleagues (Neville, Coffey, Lawson, Fischer, Emmorey, & Bellugi, 1997; Neville, Kutas, Schmidt, 1982) have demonstrated ASL to

[1] Speech-reading was formerly known as *lip-reading*.

be a complex language in its own right, complete with a syntax, morphological processes, and a constantly growing and changing lexicon similar to that seen with spoken languages (Klima & Bellugi, 1979; Neville, 1997; Stokoe, 1972). This research has increased the acceptance of the provision of interpreters for deaf learners (Wilcox, 1992).

The passage of Section 504 of the Rehabilitation Act provided the impetus to increase mainstreaming of deaf students in public schools. The law effectively mandates the use of auxiliary aids needed by a deaf student in a public school classroom, including the use of expert educational interpreters. The law also leaves room for the use of new technologies that could possibly be of use for students with deafness in classrooms. Since the passage of the Americans with Disabilities Act (ADA) in 1990, real-time captioning has become available for use in the classroom through stenographers and software that enable the immediate translation of the stenographer's notes into English text on a laptop computer. Unfortunately, Section 504, the ADA, and the IDEA do not provide a working definition of what constitutes a qualified educational interpreter or a qualified educational captionist. The Americans with Disabilities states in the summary of Section 28, Part 35 that

> It extends the prohibition of discrimination in federally assisted programs established by section 504 of the Rehabilitation Act of 1973 to all activities of State and local governments, including those that do not receive Federal financial assistance, and incorporates specific prohibitions of discrimination on the basis of disability from titles I, III, and V of the Americans with Disabilities Act. This rule, therefore, adopts the general prohibitions of discrimination established under section 504, as well as the

> requirements for making programs accessible to individuals with disabilities and for providing equally effective communications. It also sets forth standards for what constitutes discrimination on the basis of mental or physical disability, provides a definition of disability and qualified individual with a disability, and establishes a complaint mechanism for resolving allegations of discrimination (1990).

Neither Section 504 nor the ADA specifies what constitutes discrimination on the basis of effective communication. However, since public schools receive federal funding, they can be held accountable in this area of communication as are other public places such as courts (National Association of the Deaf Law & Advocacy Center, 2009).

Others within the Deaf community have attempted to describe what constitutes an *effective interpreter*. According to Title III of the Americans with Disabilities Act, an *expert* interpreter in educational situations is “one who is able to interpret effectively, accurately and impartially, both receptively and expressively, using any necessary specialized vocabulary”. Although the Federal government and parents of deaf children expect the schools to provide such expert educational interpreters, in many areas of the U.S. the quantity and the quality of interpreters available is restricted (Jones, Clark, & Soltz, 1997, p. 259; Stuckless, Avery, & Hurwitz, 1989). In *Best Practices in Educational Interpreting*, Seal (1998) writes that although educational interpreting is the fastest growing area of interpreting services, the majority of interpreters never attend preparation programs that specifically focus on interpreting in the classroom. Interpreting in science and math classrooms could be a problem because it would demand that educational interpreters and stenographers to have in-depth knowledge of the subject matter in order for it to be done right. The assumption that even skilled and certified sign language interpreters can provide the *same* science information as available to their hearing peers in the classroom has not been proven. This does not take into account the many interpreters used by public school districts who lack the educational training or the requisite certification, and whose presence is dictated by convenience and/or cost efficiency.

There are currently no standardized requirements for educational interpreting on a national basis (RID, 2004). Only 30 states out of the 50 states have or are developing standards for the educational interpreter. The National Association for the Deaf (NAD) and the Registry for Interpreters for the Deaf (RID) joined forces in 1992 to create more stringent testing and standards for those who wish to become interpreters for the Deaf (RID, 2009). However, an interpreter can be available for use in science classrooms but may be lacking in linguistic skills in American Sign Language *and/or* have no prior background in science, either of which would make accurate interpreting in science exceedingly difficult. Limited research has shown that educational interpreters have significantly different background and training, and they often use different *types* of sign language (Schwick, Williams, & Bolster, 1999, p. 144). This same study also showed that less than half of the interpreters evaluated met minimal standards for educational interpreting.

The major problem with use of interpreters in educational situations is that although states and schools may follow the letter of the law in providing an interpreter to a deaf student (or several deaf students in one classroom), many times the states and school districts are merely providing a warm body with inadequate training in American

Sign Language. This dilemma can be seen in such transcripts of legal rulings and government publications such as the report of the West Virginia Advisory Committee to the U.S. Commission on Civil Rights in 2002 (Appendix A)[2]. In the part of this document dealing with treatment of people with disabilities in public schools it was stated to the Commission that "…schools often hire uncertified, poorly qualified interpreters because they are cheaper than those fully qualified." Rural communities are especially having problems meeting the legal requirements of the IDEA and Section 504/Section 508 of the 1973 Rehabilitation Act as noted in a paper from the Laurent Clerc National Deaf Education Center (Wolfe, 2001). This paper discussed the limited options available to parents of deaf children in rural areas. One parent said that the lack of national standards (for educational interpreters) led to the hiring of unqualified individuals. He went on to say that "There were some deaf children who went in who knew more sign language than the interpreters" (Wolfe, 2001, p. 17). A website that keeps track of which states require certification for educational interpreting, as well as what type of certification (whether specifically for education, state or national certification) identifies 30 states. This is up from the 22 states listed as requiring certification in 2000 (Linehan, 2000).

Signing is usually supplemented with fingerspelling, which is the spelling of English words that have no equivalent signs in the manual lexicon (Marschark, Everhart, Martin, & West, 1987). Fingerspelling is also used to clarify issues and information, reinforce what is being learned, and provide correct spelling for new vocabulary as well as associate that spelling with a sign. Fingerspelling is often used to remind students of the textual word that the sign represents, and in fields such as science and mathematics

[2] This document can be read at http://www.usccr.gov/pubs/wvsac/main.htm

fingerspelling helps to introduce deaf students to new signs and new words. Often times, there are no signs widely available for specific science vocabulary, especially at higher levels of scientific education. In addition, there is an underlying problem that even skilled interpreters may not have the preparation or background to deal with science terminology that is used in the classroom. When either of these two situations exists, interpreters often fall back on using fingerspelling to fill the void in the lexicon of American Sign Language. This becomes a problem in science classrooms when the creation of significant lag-time from overuse of fingerspelling makes it impossible for interpreters to keep up with the teacher or with videos (Cokely, 1986; 1992). In addition, interpreters who have inadequate science background may not know how to spell scientific terminology correctly. As stated in a 2001 paper “From sign-to-speech if the signer has to resort to fingerspelling of proper names or unfamiliar terminology s/he may take a few seconds longer which may interfere with memory retention of what the speaker has said in the meanwhile, thus reducing the quality of the signed rendition” (Bidoli & Jane, p. 142).

1.2.2 Computer-assisted Real-time Captioning

Real-time transcription is a communication technology available for use in the classroom. This technology is the live closed captioning of the spoken word in the classroom by a stenographer who converts spoken language into text after utterance (Stuckless, 1994). The equipment usually includes a laptop computer with several cables along with a stenographic machine, as well as specialized software that allows interface between these two machines. The software includes a dictionary, a program with a logic and set of rules that selects the words, and a word processing program. Usually the stenographer sets up near the front of the classroom to the side of the teacher, but keeping the teacher within visual range. This allows the deaf student to be able to see what the teacher is doing, as well as the stenographer and computer. Starting in 1982, steno-based systems began to be used in classrooms for deaf students at the Rochester Institute of Technology (Stuckless, 1983). Those who are late deafened often prefer this particular communication technique. However, it was quickly incorporated into the classrooms for any deaf students, including secondary level, without the necessary prior research into the effectiveness of its use in those classrooms (Clark, 1998; Preminger & Levitt, 1997).

Deaf students generally do learn more when visual educational materials, such as films or television, are presented with captioning (Block & Okrand, 1983; Murphy-Berman & Jorgensen, 1980; Steinfield, 1998). Limited research has been conducted with real-time captioning as a means of conveying science classroom information to deaf students in classrooms and the accuracy of the information delivered (Marschark et al., 2006). This research showed that deaf students in both secondary and post-secondary classrooms using real-time text performed at a higher level, than when using sign or both methods of communication in conjunction with one another. Much of the current research available on the impact of captioning has been conducted with post-secondary students at the National Technical Institute for the Deaf (NTID). Stinson and Macleod (1980) studied the differences between information gleaned by deaf students from interpreters and that received from printed versions of lectures. They found that deaf college students recalled more idea units rated as important when the lecture was printed, as compared to interpreted lectures.

More recently, the research at NTID has focused on C-Print, a speech-to-print methodology similar to Computer-Assisted Real-Time Captioning (CART). The overriding difference between CART and C-Print is that CART transmits verbatim reports, while C-Print is not verbatim (Davis, Francis, & Harlan, 2000). Since C-Print is not verbatim, this cuts down on lag-time in reading in comparison to CART. Most of this research has concentrated on the technology's use for postsecondary students and for adult learners (Stinson, et al., 1999). This may mean there will be a difference in the reading abilities of students who have successfully entered post-secondary education, and the reading abilities of deaf students at the secondary level, especially when it is known that more than 30% of deaf students leaving high school are functionally illiterate (Traxler, 2000).

1.2.3 Impact of Reading Skills

There has been a large amount of research over the last 70 years showing that many deaf students are poor readers (Geoffrion & Schuster, 1980; Marschark et al., 1993). Research has shown that there may be differences in immediate memory span for verbal material for deaf learners (Hanson, 1982). More recent work found that while deaf learners have no physical deficits in visual perceptual skills, they did have differences in recall or memory of serial position, which would impact reading skills (Clark, 1998). Deaf learners also are less likely than hearing learners to integrate text information in units of concepts, which also may play havoc in reading and the integration of concepts with a priori knowledge (Marschark et al., 1993). CART has been incorporated into classrooms without consideration of this pertinent information about deaf learners' reading challenges, or the divergent memory processes they use. There has been a blanket assumption on the part of schools that elementary and secondary deaf students can cope with the level of technology used in CART. There has been little research conducted to demonstrate the effectiveness of using CART in K-12 classrooms with deaf students.

1.3 Purposes of Study:

It is necessary to examine how deaf students' comprehension of science in mainstream classrooms may be impacted through the use of support services and to determine the accuracy of those modes of communicating classroom information. The question to be addressed through this study is:

> How much of the spoken information available to hearing students in the classroom is transmitted through the written word by CART or through American Sign Language by interpreters?

This study examines the inclusion or omission of key words as relevant to understanding of the science content, when delivered through captioned text or signed format.

1.4 Definitions of Terms:

Deafness: Even though no deaf students will participate in this study it is necessary to describe the students who might require the services of communication providers. For the purposes of this paper, a 'deaf' student will be defined as any student with hearing loss in the following ranges: 500, 1000, and 2000 Hz (Hertz). The rationale for this is that these are the tones of speech perception and it is the speech of teachers and student-peers that these deaf students need to have communicated to them (Marshark et al., 1993). This includes any child with a loss of 70 decibels (dB) and higher. Usually these children are categorized by audiologists as either those with a hearing loss of 70-90 dB considered “severely deafened”, and those with hearing loss greater than 90 dB regarded as ”profoundly deafened”. There is an ongoing discussion between medical personnel, audiologists, parents, and even those with deafness, as to the application of the terms *hard-of-hearing* and *deafness,* and when these divergent definitions apply. Depending upon who is asked, a child can be considered hard-of-hearing or deaf, but since this study is concerned with the communication providers to these students rather than deaf students themselves, the argument is moot.

American Sign Language (ASL): For the purposes of this study, the interpreters will use ASL, rather than one of the other ‘manual’ languages, such as Pidgin Sign English (PSE) or Signing Exact English (SEE). Educators created these manual languages in the late 1960’s and early 1970’s in an effort to utilize sign language in more English-type syntax. The thinking of the day was that using manual sign in English syntactical format would increase the English language skills of deaf students. The Registry of Interpreters for the Deaf (RID) recognizes all of the manual languages used, and has yet to establish permanent guidelines advocating one type of educational interpreting over the others. Rather RID’s emphasis is on quality of the translation in the communication mode preferred by the person being served. This is stated in the NAD-RID National Council on Interpreting Code of Professional Rights and Responsibilities (2004): “Interpreters render the message faithfully by conveying the content and spirit of the speaker using language most readily understood by the consumer (pg. 4).”[3] In general, interpreters have differing degrees of skills in signing ability and exposure to the different manual languages, as well as exposure to working and socializing with the deaf.

[3] See http://www.rid.org/coe.html

This study will not determine the accuracy of the ASL used by the interpreters. The emphasis in this study is on the accurate delivery and depiction of science key science words by the interpreters.

Steno-based Speech-to-Text or Real-time Captioning: This method of information delivery uses current technology to provide accommodation for deaf students in public classrooms. It uses a stenographer or captionist in conjunction with a laptop computer to provide both verbatim real-time captions as well as a copy of that text material for future reference.

2.0 CHAPTER 2: LITERATURE REVIEW

2.1 Current Research into Learning in Deaf Students

There has been an assumption that students with hearing loss are unable to be successful in achieving a liberal education because they are unable to process language in the same way as hearing students. Rather than achieving language easily through hearing, deaf children must rely upon visual input, with exposure to manual language often coming at a later developmental time in comparison to hearing children who learn aural language at the usual pace. The research on which these assumptions were based used the English language as the means not only of delivering educational concepts to deaf students, but also to test these students (Myklebust & Brutten, 1953; Olson, 1967). This early research was typical for most language minorities of any kind, to teach and test not in their primary language, but in English. For the most part, this is recognized now as a major error in testing for any minority populations, and especially for the deaf whose primary language is ASL or some other form of manual language.

As Marschark, and colleagues (2002) stated in their recent book *Educating Deaf Students*, reality for deaf students is not as easily understood, as previous research would have us believe. Even though it would be nice and politically correct to assume that deaf students are basically the same as their hearing peers except for the fact of not being able to use their ears, this is not a truism. Most deaf children are born into hearing families, and this situation changes the norms that are most likely expected for hearing students (Marschark et al., 1993). Most important, these children all have significant language differences from each other as well as from their hearing peers. This includes when they first achieve specific critical points in their mental and social development. If anything, deaf children vary as much or more than hearing children because of onset of hearing loss, type of hearing loss, and the cause of hearing loss. Added to this are the divergent familial backgrounds and the ways that parents decide to cope with the child's hearing loss: Acceptance and use of manual language in the home, decisions on hearing aids or cochlear implants and the immense amount of therapy that goes into using such technology, and exposure to early intervention programs. This knowledge impacts researching educational issues for deaf students since it cannot be assumed that each child with hearing loss, even if that hearing loss is similar to another child being tested, will test the same.

More recent research by Al-Hilawani has indicated that deaf learners can be competitive with hearing students in metacognitive development (Al-Hilawani, 2000; 2001). Contrary to previous research and the continued beliefs of many educators, audition and spoken language are *not* the only crucial factors in either the intelligence or the ability of deaf learners to acquire knowledge. Most research completed in the past on deaf learners has focused on the delays caused by slower language development. When intelligence testing is conducted in a manner to minimize the use of language for comprehension and completion of tasks (but is controlled for other cognitive variables), then testing demonstrates that the intelligence of deaf people is similar to their hearing peers (Braden, 1994)

Researchers and educators have reached a tentative consensus that the lack of audition *can* have minimal or no effect on intelligence, provided the hearing loss is caught early and the deaf child has access to language within the family. Research done by Zweibel demonstrated that deaf children born to deaf parents with deaf siblings tested as well cognitively as hearing students due to early exposure to manual language (Zweibel, 1987). The differences often seen in intelligence testing of deaf children are usually admitted to be evidence of the limited *experience* of deaf children in early life. This is especially true for children with deafness who are born to hearing parents. Deaf children born to deaf parents, who are exposed to early manual language, have always been more successful in educational achievement (Bonvillian, Orlansky, & Novack, 1983; Brasel & Quigley, 1977; Mindel & Vernon, 1971).

Deaf children of deaf parents are more likely to be immersed in the deaf community, and more likely to go to residential schools. The primary advantage of these deaf learners is that they have early access to incidental information, including science (Lane, Hoffmeister, & Bahan, 1996). This incidental information can come from parents reading books to their children and answering questions, access through captioning to such television programs as *Sesame Street* and *Bill Nye, the Science Guy* that can be a boon to teaching reading skills, and access to other opportunities such as local science museums with parents who can participate and explain new material to them (Kirkland, Byrom, MacDougall, & Cororan, 1995; Neuman & Koskinen, 1991). These children also have increased peripheral visual attention skills in comparison to deaf children born to hearing parents (Bavalier, Tomann, Hutton, Mitchell, Corina, Liu, et al., 2000). The importance of this issue as pertains to this study is that ability to pay visual attention to more than one thing for these deaf children is likely to be enhanced over that of deaf children born to hearing parents and hard-of-hearing children. Since most deaf children of deaf parents are enrolled in residential schools, while deaf children of hearing parents tend to go to public schools, this difference in visual acuity and attention becomes important when involving interpreters and CART personnel in the education of deaf students. It is to be expected that increased experience and access to educational opportunities and information are much more critical to educational success than conformance to the language skills as normally demanded by intelligence testing (Braden, 1994).

Research has also shown that deaf students learn more when material is presented in more than one modality, such as graphics or movies with closed captioning (Brickman & Workman, 1995; Nugent, 1983; Steinfield, 1993). Dual coding of science concepts has been seen to be more comprehensible and memorable in hearing students, than providing science information in just one modality such as lecture format (ChanLin & Chan, 1996). Access to such television programs as mentioned above is only valuable for deaf children if there is equal access to closed captioning of those programs. If in fact dual coding increases ability in conceptual understanding for hearing students, then increased visual input should be even more significant in the learning of deaf students who use visual processing over auditory processing on a daily basis.

What is not known is whether the manner of visual input (sign versus printed word) makes a significant impact on *how much* is retained. It is also not known whether there may be interference problems involved when deaf learners are expected to use different means of getting information in science classrooms or when they are expected to alternate their attention between an interpreter or CART personnel *and* look at information being given on the blackboard or through videotape. Interference as a problem in psychology and in education became important as researchers tried to determine *how do students decide what to pay attention* to? Interference can occur when students have to pay attention to multiple and competing items or events. Given that the brain has limited resources especially as pertains to short-term memory, attention and learning may be compromised when asked to do too many things at once (see Dempster & Brainerd, 1995). Interference *may* arise when deaf learners are expected to pay visual attention to an interpreter or CART, in addition to the expectation to pay attention to what the science teacher may be doing (using graphics, overhead projectors, and writing on the blackboard, demonstrating an experiment, etc.).

Another factor involved in delivering information to deaf students is that deaf students can have good ASL skills and continue to be poor readers. This includes reading of English both in text and when the interpreter needs to fall back on fingerspelling to convey information for which there are currently no signs available, or the interpreter is so poorly prepared in the subject matter they are not familiar with the signs available for that topic (see report on Civil Rights Issues in West Virginia in Appendix A). It would be possible that even if captioning provided more accurate information, the students may receive a higher percentage of that information through their first language (ASL), then through their second language (English).

Much of the emphasis in research on what deaf students understand has focused on instructional strategies, English reading levels, and the general ‘abilities’ of the deaf students. Very little research has been conducted relative to the accuracy of concepts delivered to deaf students, and the impact of that delivery on the conceptual understanding of those students. A study of the correctness of the information (key science words) delivered to deaf students by communication providers is a logical step toward the examination of deaf students' comprehension of conceptual information in the classroom.

2.2 Signing and Learning

Although manual languages have been used in classrooms in the United States since 1817 when Laurent Clerc and Thomas Hopkins Gallaudet opened a school for the deaf in Connecticut, the use of American Sign Language in the public school system is still relatively new (Lane, Hoffmeister, & Bahan, 1996). As oralism came to the forefront of deaf education, sign language was banned in most schools. Sign language began to become publicly acceptable in the 1960s as the civil rights movement impacted the educational rights of the disabled and the deaf. Provision of interpreters came about in response to the passage of the 1973 Rehabilitation Act and the passage of PL 94-142, the Individuals with Disabilities Education Act. For some deaf children, interpreters became part of their right to an appropriate education in the least restrictive environment during the last 25 years of the twentieth century (Seal, 1998). Although there is significant research into ASL as a language, research on the art of educational interpreting is still in its infancy.

Signing can have a facilitative effect on learning and memory in deaf students, in comparison to aided hearing or lip-reading of the spoken word (Parasnis, 1979; Sensenig, Mazeika, & Topf, 1989). Words that can be expressed using a single sign have been demonstrated to be more readily coded and retrieved than English words that do not have a sign language equivalent (Lang & Pagliaro, 2007; Odom, Blanton, & McIntyre, 1970). This advantage may lie in the fact that many signs *may* provide an image of the word, and images are more readily coded (Petersson & Siegal, 1995). Another benefit may lie in the fact that a symbolic representation takes up significantly less ‘space’ in memory than a fingerspelled word or a written word (Parasnis, 1979). These possibilities have been studied to some extent under the dual coding theory as proposed by Paivio (1971).

In Paivio’s dual coding theory, information can be transmitted through a verbal or a visual code in an independent manner. Written words, or signs, which activate both types of coding (verbal and visual), are more memorable than aural words that activate only one type of coding. The more likely the word or the sign can be referenced because of imageability, the more easily that word or sign can be referenced. Conlin and Paivio (1975) have showed the facilitative effect of words that are easily converted to an image. They demonstrated that signs that have a high degree of imagery association in their usage were used more often, and so were remembered more than signs that were less iconic or graphic in representation. Research has also shown that sign language can have a pivotal role in the development of critical analytical abilities and in conceptualization for students in whom vision is the primary source of input (Levine, 1986).

Other studies using lists of words or paired-associate learning tasks demonstrated that signed words are much more likely to be recalled than words with no equivalent signs that are fingerspelled (Bonvillian, 1983; Conlin & Paivio, 1975). However, research into the impact of signing on retention of subject matter and content, in comparison to other modes of communication such as CART, has been very limited. One such study, conducted in 1980 comparing signing versus the printed word, involved college students (Stinson & Macleod, 1980). This study used a videotaped presentation of a lecture with an interpreter and a printed copy of a second lecture (since in 1980 the technology was not available for CART). This study found that at the postsecondary level, deaf students retained more conceptual information from the printed lecture than they did from the interpreted lecture.

American Sign Language is a language that is evolving constantly like all languages. The increased pace of scientific and technological discoveries, and the amount of science information that students are expected to learn for standardized testing, however, has placed a demand for a new vocabulary in science. The escalation of the rate of this information has made it very difficult to keep up with in creation of new signs (Rasmus & Allen, 1988). As Rasmus and Allen said in the aforementioned paper "In biology teaching an increasingly complex terminology has created a gap between ASL and spoken words for technical terms (p. 314)." They go on to say that "…there is a strong need to merge scientific and technical terminology into the language of the deaf (p. 315)." Yet, it has been demonstrated that deaf learners can be very fluent and creative in the use of signs to conceptualize and incorporate meaning (Zweibel & Mertens, 1985; Marschark & West, 1985).

As with interpreters in any language, sign language interpreting may be fraught with miscommunication and discrepancies. In *Best Practices in Educational Interpreting* Brenda Seal stated that "…interpreters make errors, some are inconsequential, some are embarrassing, some are humorous. When learning is at stake, interpreter mistakes can be serious" (Seal, 1998, p. 179). Johnson (1991) found that interpreters who are unfamiliar with the subject matter they are interpreting tend to make more errors, and more significant errors. Johnson studied deaf college students who were receiving interpreting in their anthropology classes, and found that those students were experiencing considerable confusion due to errors made by the interpreters. Some of the confusion happened because of bilingual diglossia, the switching back and forth by interpreters between English-like varieties of manual language and ASL. This can be a significant problem for deaf students whose primary language is ASL, and who are unfamiliar with Pidgin Signed English (PSE) or Signing Exact English (SEE). It can also be a problem for hard-of-hearing or newly deafened students who are learning ASL as a second language (Johnson, 1994).

Fingerspelling is most often used by teachers or interpreters when there are no available corresponding signs for English words, or when the person delivering the information needs to associate the written English word with an evolved sign. In science classrooms, the significantly more complex terminology causes an even wider gap between signs and spoken words to exist for communication personnel. Too many times in science classrooms, it has become necessary for these personnel to resort to fingerspelling, even when it is known to be slower and less effective than ASL (Caccamise & Blasdell, 1978). Caccamise & Blasdell stated "Reception of fingerspelling is a difficult skill to master...Interpreters at the National Technical Institute for the Deaf (NTID) have reported that deaf college students often have difficulty reading fingerspelling (p. 879)."

These researchers go on to say that fingerspelling "…even under optimal conditions may disrupt the normal flow of the visual and auditory aspects of speech (Caccamise &Blasdell, 1977). When interpreters are slowed down with continuous fingerspelling, this tends to increase *lag* time. Lag time (or ear-voice span) is the difference in time between the interpreter hearing the spoken word, and the actual production of that spoken word in either sign or fingerspelling (Cokely, 1986). It should be expected that lag time does increase along with the difficulty of the subject being interpreted. Caccamise and Blasdell (1977) also found that fingerspelling can be difficult for the person receiving it, and communication of information can be hampered by the use of too much fingerspelling during a discourse.

Most research into fingerspelling has been primarily concerned with the *reception* of fingerspelling and the facilitative effect of fingerspelling when done in sentences, rather than in isolation (Caccamise & Blasdell, 1977; Erber, 1971). Research has been conducted into how fingerspelling is perceived by the person *receiving* the fingerspelling. Earlier studies determined that the amount of words recognized were significantly less if fingerspelling is used alone, compared to fingerspelled words embedded in a signed sentence. These limited studies done also show that increasing the distances between the fingerspeller and the student has a detrimental impact on the clarity and understanding, similar to that seen with lip-reading and even in acoustic communication (Taaffe, 1958). Other studies have focused on the use of fingerspelling to enhance English language literacy (Johnson, 1994). Fingerspelling has traditionally been used in most manual languages and their English equivalents such as PSE to introduce novel words or technical words with no accompanying sign, and to spell proper names (Luetke-Stahlman & Hayes, 1994).

One important study of the contribution of fingerspelling to word recognition found that deaf students recognized more individual words *in print* than they recognized in fingerspelling. This research also found that these students were better able to classify signs and printed words than they could fingerspelled words (Mayberry & Waters, 1987). This indicates that fingerspelling, while used widely by interpreters in science, may not be helpful to students in conceptual understanding. Fingerspelling has neither the graphic iconicity of sign, nor the longevity of the printed word in terms of memory. Rasmus and Allen (1988) found that students who were exposed to biological concepts under conditions of using ASL signs versus using fingerspelling for those signs retained the concepts for those words better when they were signed than when they were fingerspelled.

2.3 Closed Captioning and Learning

Captions are subtitles to allow the deaf to see spoken language and sounds that they normally cannot hear. Captions are converted to electronic code by companies such as the National Captioning Institute (NCI) or VITAC, and are inserted in the television signal. There is significant research showing that closed captioning has been helpful in increasing the reading skills, not only of people who are deaf, but also those with learning disabilities, and for those with English as a second language (Kirkland, Byrom, MacDougall, & Corcoran, 1995). One study found that slower paced captioning on a video allowed 'at-risk' students to learn more, even more than using traditional print material (Meyer & Lee, 1995).

Closed captioning of movies and educational material has been available for over 20 years (National Captioning Institute, 2002). The ADA and the Television Decoder Circuitry Act mandated that all televisions made by mid-1993 had to include closed captioning decoder microchips in the sets, and for the most part, captioning is automatically done for most media (with commercials and public service messages being the lone standouts in this area).

Live (or real-time) captioning of television, conferences, the Internet, and educational videos is done the same way as CART is done using stenocaptioners with a special steno keyboard (Robson, 1998). These stenocaptioners listen to the same broadcast as the consumers, and write what they hear phonetically at a rate of close to 250 words per minute. Computer software then translates the phonetic shorthand into English and the captioning is sent through a modem to the television station (or in a conference situation, to the screen).

Whenever captioning is carried out at this rate of speed, there are bound to be errors made. These errors most often tend to be typos, grammatical errors, and misspellings of terminology that are not in the program's dictionary. CART is carried out the same way as real-time captioning except that the computer software sends the English translation to a laptop computer in front of a person who is deaf. The major difference between real-time captioning and CART then is the lack of video or visual accompaniment on the screen.

CART professionals are usually trained for legal work and medical transcription, and only gain experience in education when working in educational settings. This method of information delivery is also called CAN (Computer Assisted Notetaking). They usually attend a 2- to 4-year training program at a vocational and technical college, which has been approved by the National Court Reporters Association (NCRA). Most states require court reporters to be either a notary public or to pass a state certification test given by a board of examiners. A court reporter becomes a Certified Court Reporter upon completion of this examination. The NCRA itself confers the designation of Registered Professional Reporter (RPR) on those who have passed the NCRA's 2-part examination and take continuing educational classes in the field. The Occupational Outlook Handbook states the following: “Stenotype machines used for real-time captioning are linked directly to the computer. As the reporter keys in the symbols, they instantly appear as text on the screen. This is used for closed captioning for the hearing-impaired on television, or in courts, classrooms, or meetings. In all of these cases, accuracy is crucial because there is only one person creating an official transcript” (U.S. Department of Labor, 2001, p. 1). Certification for CART has not been standardized across the U.S. yet, and so there is no guarantee of expertise in CART or in provision of the special requirements needed in science education.

CART as live or real-time closed captioning is often used for deaf individuals who do not know American Sign Language. It is also used for Deaf students in areas in which it is difficult to obtain skilled sign language interpreters, such as rural areas (since counties with court houses will require court stenographers). CART reporters use the same technology as court stenographers except that the readout is provided *immediately* through a laptop *using* specialized software such as *Caseview II* by Stenograph (2002). Verbatim text is created. CART provides the client with a printed transcript at the end of the session, alleviating the need for both an interpreter and a notetaker in the classroom.

The ability to use CART well is mainly dependent upon the reading skills of the person using CART. Originally intended for use by the late-deafened and in conferences, the technology assumes that the audience will have good reading skills. English skills are more important in using CART, than in reading an interpreter using ASL signs for English words or in reading a textbook where the print is stationary and can be referred back to. In CART, the text is conveyed on limited space of a laptop computer screen, and the text is in constant movement. CART cannot be compared to reading a textbook because of its movement, and also the fact that the student consumer is unable to control how fast it goes, or refer backwards in the text when needed. The text in CART goes from left to right, similar to typing on a word processor, but it scrolls upwards suddenly. The amount of this leap of the page depends upon the system and the software being used. Some CART texts move up line by line, while others may jump 4 to 5 lines. In some cases the software can dictate that an entire paragraph can leave the screen after a certain amount of typing done by the stenographer. The speed with which the stenographer does shorthand into her machine dictates how fast the text on the screen moves. The usual speed for stenocaptioners (required for certification) is between 225 to 250 words per minute. So a stenocaptioner could theoretically capture everything uttered at the normal rate of speech at 180 words per minute.

Studies on captioning speed have been conducted by Carl Jensema of the Institute for Disabilities Research and Training. He found that when video segments captioned at different speeds were shown to 578 viewers who were deaf, hard-of-hearing, or hearing they preferred a rate of closed captioning is approximately 145 words per minute (Jensema, 1998). This was the speed at which viewers felt most comfortable, and in closed captioned television programs, the mean rate is actually 141 words per minute. Some participants were able to adapt to higher speeds of captioning, with the rate at which the viewers had difficulty in keeping pace with the captions at about 170 words per minute. Surprisingly enough, the hearing people wanted slower rates of captioning. Those who found it necessary to ‘read’ their television on a regular basis were much more comfortable with higher speeds of captioning. Age, sex, and even education were found not be related to caption-speed preferences.

Even the highest rates of captioning found comfortable for viewers are not within the boundaries of the rates of captioning by stenographers for educational purposes. In other words, CART may be guilty of producing too many words too quickly for understanding to take place, especially for younger deaf students or students with poor reading skills.

Captioning research has demonstrated that regular captioning used on films, television, and the Internet *can* assist deaf learners in science literacy and in understanding science concepts (Koshkinen et al., 1993; Neuman & Koshkinen, 1992). However, a concern has risen between the uses of verbatim or edited captioning. One study used hearing students who viewed rewritten science materials (meaning the text was simplified). They did much better on the comprehension posttest then did students who accessed the regular material (Williams, 1968). A later study done with deaf students found a significant increase in understanding when the items being tested were phrased differently using a simpler language scheme (Bornstein, 1971).

Reading grade level and rate of captioning seems to be highly correlated with understanding when captioning is used (Braverman & Hertzog, 1980; Hertzog, Stinson, & Keiffer, 1989; Lewis-Jelinek & Jackson, 2001). Rate of captioning means the amount of time the words are left on the screen. An example of this is if a five word caption is left on the screen for 5 seconds, each word is permitted one second for reading rate (with a result of 60 wpm). In the study done by Braverman and Hertzog it was determined that when a lower rate of captioning was used (as well as a lower complexity of language), the deaf students were able to understand and comprehend more of the materials involved in the study. However, if captioning is slowed down too much (<90 wpm), the students found the input of information frustrating.

The noteworthy difference between edited captioning such as used in the study above, and live captioning as offered by CART personnel is the movement of text on the screen and the higher rate of captioning as done by these personnel. It is known that live captioning has significantly more errors than prerecorded (also known as off-line captioning) captions (personal correspondence with the NCI).

It is to be expected that CART in the science classrooms will also have more errors when the stenographers are unfamiliar with science, just as would be seen with interpreters who are unfamiliar with science. There is also a problem if the CART personnel use a loaded dictionary that is provided for other types of jobs they usually do, such as legal work in courthouses. These dictionaries will be unfamiliar with science terminology, and will often interpret the phonetic shorthand incorrectly, possibly presenting legal or medical terms that are incorrect.

CART personnel in educational environments usually take the floppy disks containing their recent classroom work home with them, where they correct their errors and then give the students a copy of their complete classroom dictation. Depending upon the age and grade level, this can represent a large reading assignment. If the CART personnel do not recognize a mistake due to their unfamiliarity with the science, or if the loaded dictionary does not recognize the phonetic spelling of science terminology, the error may remain on the student's printed copy. Grammatical mistakes may be minor, but conceptual mistakes will have a higher probability of negatively influencing deaf students' construction of scientific knowledge.

Past studies have looked at the reading rate problem in conceptual understand for deaf students using CART. Studies have not been done using high school students and the possibility that the delivery of concepts by the third person communicators may be responsible to a good extent for the inability of these students to understand the concepts delivered. In fact, most studies have concentrated on postsecondary students and reading levels versus high school students and correctly delivered concepts by third person communication providers. The possibility exists that the third party communicators, may play a significant role in developing the science misconceptions in deaf learners. If certain concepts are incorrectly delivered to a deaf student what influence will this have on the construction of knowledge which will follow in the same lecture and on future concepts? These are problems that need to be researched.

3.0 CHAPTER 3: METHODOLOGY

The primary goal of this study was to determine the accuracy of content delivery of third person communicators translating an educational video for an audience. The audience in this case was a camera. The third person communicators, the sign language interpreters and CART personnel, were told to imagine the audience as a group of deaf students. The number of correctly delivered key science words was evaluated in each of three15-minute segments of NASA CORE videotapes.

3.1 HYPOTHESIS

Based on the review of the literature it is expected that there will be less content accuracy for the two support services available to deaf students, sign language interpreters and CART personnel, in comparison to the original audio message received by their hearing peers. It is not expected that the number of key words needed to understand science concepts as delivered by sign language interpreters and the number of key words conveyed by CART personnel through stenocaptioning to a laptop computer will differ. The first expectation will be examined by calculating percentages. To examine the difference between the content delivery accuracy of the interpreters and captionists, a null hypothesis is presented below.

3.1.1 Null Hypothesis

There will be no difference in the number of the key science words included in the translations from spoken English to ASL by interpreters as compared to those included in translations by CART personnel through stenocaptioning. The number of key science words delivered by these third person communication providers will be equivalent. This expectation, that there would be no difference between the two translation approaches, will be tested with ANOVA.

3.2 PARTICIPANTS

3.2.1 Interpreters

There were two groups of participants in this study. The first group consisted of 6 sign language interpreters from Pittsburgh and surrounding areas. Three of these interpreters were certified by the Registry of Interpreters for the Deaf (RID), the recognized national organization established in 1964 to provide interpreting for deaf persons, 3 were not certified but were merely freelance interpreters for the deaf. No special attempt was made to find interpreters with prior training in interpreting in education or in science. The interpreters were not selected on the basis of education or certification. Rather interpreters were obtained as local school districts obtain interpreters for their deaf students in public schools, through local agencies and word of mouth (Table 1). The information for this table came from the background demographic questionnaire filled out by each interpreter in Appendix B. All of the interpreters had post-secondary training except for one. Four of the interpreters had certification through the Registry for Interpreters of the Deaf. Every interpreter had taken several classes in science in high school, while one interpreter had taken no science in college, and one interpreter had not gone to college. All of the interpreters had had experience in interpreting in science or medical situations. Only two of the interpreters had not attended social activities for the Deaf.

Table 1: Characteristics of Interpreters

	I-1	I-2	I-3	I-4	I-5	I-6
Certification	Yes	Yes	No	No	Yes	yes
Experience interpreting (years)	5+	5+	1	1	5+	5+
Post-secondary education	Yes	Yes	Yes	Yes	No	Yes
High school science	Yes	Yes	Yes	Yes	Yes	Yes
College science	Yes	Yes	Yes	No	No	Yes
Experience in medical/science contexts	Yes	Yes	Yes	Yes	Yes	Yes
Common activities: 1. Unrelated 2. Science/Medical 3. Deaf social	 Yes Yes Yes	 Yes Yes Yes	 Yes Yes Yes	 Yes Yes No	 Yes Yes No	 Yes Yes Yes

3.2.2 Computer Assisted Real-Time Captioners (CART)

The second group of participants included 6 CART (computer real-time transliteration) personnel. Two CART personnel were obtained through recommendations from the National Court Reporters Association Professional Locator (PSL) and four from local court stenographers who are also used by the University of Pittsburgh's Office of Disabled Student Resources (Table2). The information for this table came from the background demographic questionnaire filled out by each captionist in Appendix C. The biggest differences between the captionists was that C-3 and C-4 had 2 years and less than 6 months of experience respectively, while the rest of the captionists had more than five years of experience. The captionists all attended special programs to learn courtroom stenography for two years, and they all had certification. Only one captionist had ever had experience in medical or science contexts.

Table 2: Characteristics of CART Personnel

	C-1	C-2	C-3	C-4	C-5
Certification	Yes	Yes	Yes	Yes	Yes
Experience transcribing (years)	5+	5+	2	<6 months	5+
Post-secondary education	Yes	Yes	Yes	Yes	Yes
High school science	Yes	Yes	Yes	Yes	Yes
College science	No	No	No	No	No
Special training for education	No	No	No	No	No
Special training in science/medicine	No	No	No	No	No
Experience in medical/science contexts	No	No	No	No	Yes
Common activities 1. Unrelated 2. Science/Medical 3. Deaf Social	 Yes Yes No	 Yes Yes No	 Yes Yes No	 Yes Yes No	 Yes Yes No

Locating CART personnel in Pittsburgh turned out to be a very difficult task. According to Monette Benoit, a contributing editor to the Journal of Court Reporting, in some areas of the United States CART is the primary method used for high school students, college students, and for late-deafened adults in getting information while in the classrooms.[4] In other areas of the U.S. where there are large communities of Deaf

[4] Benoit, Monette. (2003). Personal correspondence.

persons, good interpreters are available so CART has not yet caught on for providing information for the deaf in classroom situations. Pittsburgh is one of the cities where CART personnel are really still primarily legal reporters, and if they were used in classrooms at all they were used at post-secondary facilities, not in the high schools. Not only was it very difficult to find CART personnel who participated in classroom environments, it was also difficult to find these personnel who had either the training in educational reporting or access to the correct dictionaries to be used in the classrooms.

3.3 Materials

Videotapes from NASA's Central Operation of Resources for Educators (CORE) were used. [5] This NASA program provides multimedia for education. Much of the material deals with the space industry, but the videotapes, slides, and CD-ROMs also cover such topics as weather, life sciences, energy, engineering, and mathematics. The science in CORE is current, accurate, and precise; and most of the CORE educational material has been consistently closed captioned for the hearing impaired, making it very easy to develop transcripts of each of the video segments. However, in this study, the captioning was not turned on for the CART or the interpreters to use.

The author and a faculty advisor to this project viewed the videos, and selected three 15-minute segments from three different videos on the basis of the quantity of different science information available within those minutes. The topic of the first tape is hurricanes. The topic of the second tape is a satellite system developed by NASA that can monitor weather conditions over the oceans. The third tape is also concerned with satellites, but the major focus is on El Nino and global warming. Master transcripts of the audio portion of each fifteen-minute segment were made for each tape.

[5] Information concerning this program can be found at http://core.nasa.gov.

Each word necessary for understanding the science information in a video was counted as a "key word." For example, in the sentence "El Nino is an ocean event that has far reaching consequences", eight "key words" in the line are counted as critical to the translation (the word 'an' and 'that' being excluded). This number was reached in consensus among three raters who looked at the original transcripts from the three video segments. These three raters each had significant experience in science, as two worked in laboratories and one is in science education.

3.4 Procedures

Each third party communicator participant was tested individually. First, each participant provided information on his/her background and experience. To avoid influencing the way that the participants provided their service, no science pretest was administered on the topics. The participants had no prior notification as to the type of interpretation/transliteration that would be required from them, or the skill level required to be able to accurately deliver the key science words. This lack of preparation is common for school based interpreters in science classrooms.

Each participant was asked to listen to the videotapes and interpret or caption the complete 15-minute segment. Interpreters were asked to sign an informed consent form to allow them to be videotaped while they interpreted. The CART personnel were given floppy disks to put in their laptop computers on which to record their transcription of each videotape segment. The videotapes and floppy disks were collected at the end of each session. All participants were told to interpret or transcribe as if this were a real classroom in which they could not stop and repeat information, or stop and correct information. Each participant was to interpret or transcribe three 15-minute videotaped segments.

Interpreters stood next to a television on a stand. The interpreters were facing the camera, as they would face students in a classroom. The camera facing the interpreters captured the interpreters' transcription of the 15-minute video segments. Interpreters were not told to use American Sign Language or Sign English. If the interpreters asked which language was preferred, they were told to interpret as they normally would for a deaf student in a public school classroom. The videotaped transcriptions were later examined and the number of correctly delivered science words was counted.

CART personnel were given limited information concerning the videos. Five asked questions about the content of the videos, and were given the same information that the interpreters were given. CART participants were set up in front of a television with VHS capacities. They were told to start when the audio portion of the videotape started and the transcripts were gathered up after the CART personnel were finished. CART transcribers were not allowed to make changes to their transcripts (which they often do when providing services for post-secondary students, and sending the corrected documents via the computer). Of interest in this study was the text that would be on the laptop computers within the classroom for deaf students to read in real-time.

3.4.1 Scoring the Transcriptions

The author, who uses ASL interpreters herself, analyzed the content of the videotaped films of the interpreters. Another sign language interpreter as well as a teacher of the deaf viewed the videos of the interpreters to verify the accuracy of what was being signed.

Two science educators with post-secondary education in science viewed the CART transcripts and analyzed the transcripts. One of the science educators worked in a variety of biological laboratories at the University of Pittsburgh, assisting in writing articles for journals pertaining to the laboratory work she did. The second reviewer had worked in labs dealing with Alzheimer's disease and HIV/AIDS for seven years, and has taught science classes in chemistry, cell biology, physics, meteorology, environmental science, geology, anatomy and physiology for six years.

They also had the background to identify content delivery errors by the CART personnel. They were told to highlight where conceptual problems existed.

3.4.2 Coding the Transcriptions

The coding method used with these tapes was based on the master transcripts of the key science words correctly delivered, rather than on the linguistics of the signing used by the interpreters or the English grammar used by the CART personnel. The importance of an enhanced vocabulary to understanding science concepts cannot be emphasized enough. Studies have been conducted that demonstrate how use of quality vocabulary leads to increased vocabulary and concept acquisition, even in students with culturally and linguistically diverse backgrounds (Joe, 1995; Lee, Fradd, & Sutman, 2006). Correct vocabulary useage aids in activating prior knowledge, helps provide definitions to words used in multiple contexts, gives understanding to future context, and aids in generating deep processing and memory acquisition of concepts (Literacy Matters, 2009).

These key science words were identified in the transcripts by the three science educators reviewing the CART transcripts. Any word that was vital to understanding the meaning of the science concepts was counted. For example, in the sentence "Hurricanes can form in the Atlantic, Pacific, and Indian Oceans", the only words not needed as key words are "the" and "and." The words 'can form' are considered together as one word. That sentence will have seven key words that need to be transcribed or interpreted. These key science words were defined as information needed to correctly answer a substantive science question based on the video. Oftentimes even the substitution of small words such as 'in' or 'on' could significantly change the understanding of a science concept.

Scoring was based on the number of key words that were needed to correctly convey the science concepts. If there were four words necessary to understand the science concepts in the sentence, the interpreter or the CART personnel could earn a total of four points for a correctly-delivered "translation".

In analyzing the CART transcripts, if the CART dictionaries did not recognize the shorthand typed into the machine, and misspelled the science content, that concept it was not counted. One example of this would be the substitution of 'U r cane' for hurricane. Mistakes made in the CART translation process were often errors of the software or dictionary, rather than human errors. For example, in one CART transcription in which the CART transcriber was using a phonetic-based shorthand, the computer dictionary translated the word "torrential" (as in torrential rains from hurricanes) into three words; 'tore', 'Rent', and 'shall', with these terms appearing on the screen as indicated. In this case, the concept 'torrential' was not correctly conveyed.

As indicated by the null hypothesis in this study, the same number of key words needed to convey the science concepts was expected from the interpreters and the CART personnel. It was understood occasionally that signs could incorporate two or more words into one sign, so this was taken into account. This happened less than expected because the rapid delivery of material in the videos did not allow enough time for interpreters to 'think' about the information, and change it into correct ASL format. If the interpreters delivered information that was inaccurately spelled (through fingerspelling) or inaccurately signed, it was not counted as an accurately signed concept. Some examples of this in these videos included the misspelling of the term 'baguio' or 'glaciers', the misinterpretation of the term 'steering' in *steering winds*, or the complete loss of the word 'convectively from *convectively active winds*. Another example illustrates a typical signing error. The statement on one video segment was 'The wind drives the ocean.' This sentence contained three concepts that needed to be conveyed: 'wind', 'control', and ocean. However, an interpreter unfamiliar with science or not fluent in ASL might misinterpret the sign 'drive.' Instead of using the ASL sign for 'control', the interpreter could quite literally say 'wind drives (like a car—both hands S-shaped facing each other at chest height like a steering wheel) ocean. This transcription would earn a score of 2/3 key words correctly conveyed.

The total number of key words from the interpreters' transcripts and the transcripts of the CART personnel were compared to the total number of key words conveyed in the NASA videos using simple percentages for the number correctly delivered. To test the null hypothesis of no difference between delivery approaches, the scores were compared for statistical significance. Then the two support services were compared to each other through ANOVA.

Significance level was set at $p < .05$, because of the small number of available CART personnel and interpreters available.

4.0 CHAPTER 4: RESULTS

Three NASA videotapes were used in this study. In Video 1: Seawinds, which was at a slower pace of delivery than the other two videos, 751 key words were identified. In Video 2: Our Home, 1,113 key words were counted. In Video 3: Data Analysis and Measurement, there were 1,279 key words in the sentences. The latter two videos employed scripts, which might account for the faster delivery of the number of key words in 15 minutes.

Table 3 contains the total number of possible key words for each video and the number each sign language interpreter delivered.

Table 3: Number and Percent of Key Science Words Delivered by Interpreters

Number possible correct Key words	Video 1: Seawinds n=751		Video 2: Earth Science n=1,113		Video 3: Data Analysis n=1,279		Mean (SD) across three videos 1047.67 (270.00)	
Interpreters	# Correct	% Correct	# Correct	% Correct	# Correct	% Correct	Mean # Correct	Mean % Correct
I-1	632	84%	771	69%	682	53%	695.00 (70.41)	68.67% (15.50)
I-2	660	88	992	89	1,066	83	906.00 (216.23)	86.67 (3.21)
I-3	577	77	664	60	572	45	604.33 (51.73)	60.67 (16.01)
I-4	461	61	817	73	676	53	651.33 (179.28)	62.33 (10.07)
I-5	641	85	1,021	82	851	67	837.67 (190.35)	78.00 (9.64)
I-6	652	87	1,086	97	967	77	901.67 (224.26)	87.00 (10.00)
Mean (SD) Across Interpreters	603.83 (75.86)	80.33% (10.23)	891.83 (165.24)	78.33% (13.62)	802.33 (191.05)	63.00% (15.0		

Individual accuracy ranged from a high of 97% by I-6 on Video 2, to a low of 45% by I-3 on Video 3. I-6, however, showed the greatest variability (the largest standard deviation across the three videos). Three of the interpreters (I-1, I-3, and I-5) demonstrated decreasing accuracy of performance across the three videos over time, while the other three interpreters did not follow this pattern. For I-2, I-4, and I-6 the second video was the easiest for them to interpret.

Between the first and second video correctly delivered key words remained constant at 80% and 78%, while the average percent correct for Video 3 dropped to 63%. Whether or not this may relate to fatigue cannot be determined in this study. A similar investigation with a larger number of participants and random assignment of the videos may assist in understanding whether fatigue is a factor in the accuracy of interpreters' delivery of science vocabulary or science content in the classroom.

At least two interpreters made sign selection errors for a single word such as 'eye' of a hurricane. For example, instead of using the sign for MIDDLE or CENTER of the hurricane, I-1 signed the word for the human EYE. Surprisingly, I-1 was one of the most experienced interpreters. Deaf students being taught weather science for the first time would likely be unfamiliar with the difference between the two concepts of an 'eye'. Other examples of sign selection errors include signing YEAR as MONTH (by I-3) or signing the incorrect *number* of subsystems in QuikScat (by I-4).

Four interpreters missed important words/signs necessary to understand the science concepts. Two interpreters (I-1 & I-3) missed the section in Video 2 where the transcripts talked about water piling up on surface of the sea in Indonesia. I-1 did not interpret WARMING OF OCEAN WATERS, while I-3 signed WARNING, instead of

WARMING. I-4, who was the least experienced and had the no background in college science, used a non-existent sign for HURRICANE. This interpreter also did not sign that a ‘Hurricane is a violent tropical storm’, but merely signed HURRICANE (wrong sign) DESTRUCTIVE WINDS and HARD RAIN. I-4 also skipped fingerspelling PACIFIC. An entire concept was not signed; AT OCEAN’S SURFACE. I-4 also did not sign AIR ASCENDS, but just signed the words BECOME CLOUDS. Interpreter 2, who was one of the most experienced and who did not miss much, did not sign that the reason for predicting weather was TO SAVE LIVES. This was a relatively minor omission. Such errors may occur when the interpreters fell behind the spoken message but the interpreting process required them to continue. Some research has shown that shortening lag time often leads to increased number of miscues (Cokely, 1992). Whether lag time is responsible for miscues needs to be researched further.

On occasion, interpreters missed an entire chunk of key science information when lag time (the time between the original message and the delivery of that message by the interpreter) increased. For three of the six interpreters this occurred at the point in Video 1 where there was a discussion of the formation of hurricanes. On the video soundtrack, four different names for hurricanes across the globe are spoken in quick succession. The spoken sentence was, *“Hurricanes are given other names in other countries such as typhoon in Southeast Asia, a baguio in the Philippines, and tropical cyclones in Australia.”* When three of the interpreters (I-1, I-3, and I-4) reached the second name given for a hurricane, ‘*baguio*’, they hesitated, tried to fingerspell *baguio,* and missed the next two names for hurricanes and the specific geographic areas in which they occurred. One interpreter (I-4) missed the term *baguio* entirely, having had to fingerspell *"typhoon"* and later, *"tropical cyclone."* This interpreters then fell behind in the next sentences on the video. The more fingerspelling that was used, the more lag time increased. This happened when I-3 came across unfamiliar science information such as the terms '*hazard mitigation*' or '*scatterometer*'. Because she was unfamiliar with the appropriate signs for these terms, and she resorted to fingerspelling, more time was required. If interpreters did fingerspell all the names of hurricanes, they would fall behind in the following sentences. Such errors often occur when interpreters fall behind the spoken message (lag time) and are unable to produce the message as accurately as desired when the interpreting process requires them to continue (Cokely, 1986).

Under normal conditions, most interpreters are prepared to sign for two hours before needing to alternate with another interpreter. So the 45 minutes of video they were required to do for this study should have been possible without the increased rate of errors. However, there were an increased number of errors overall in the last video even among the more experienced interpreters, as can be seen in Tables 2. While the percentage of correctly delivered key words remained constant for Video 1 and Video 2 at 80%, the percentage for Video 3 overall dropped to 63%, Whether this was due to 'hand fatigue' or 'mental fatigue' was not determined in this study, but it is imperative to find out why the number of errors delivered by the interpreters increased in Video 3 while the number of errors by the captionists remained constant. If the study had used different videos for different interpreters in a different order, and accuracy decreased, it might indicate a problem with fatigue. This needs to be looked at in future studies. Another problem that needs to be looked at is what type of errors was made over time. Was it merely selection errors, deletions of words or concepts due to lag time, or misspellings, or a combination of all of these? And are the errors worse with the need to interpreter for science and math, compared to signing for English or history classes?

As shown in Table 3, two interpreters were able to deliver as many of the key words as captionists were able to for Video 2. This however, was a rare occurrence. This needs to be examined further, as to why these interpreters were able to do well on that video in comparison to the other two videos. Was it due to availability of signs for the science vocabulary in that video, or the experience of the interpreters?

Before an assumption can be made that the interpreters experienced some type of fatigue by Video 3, some specific points need to be made about the performance of some of the interpreters. Interpreter 1 had the fourth highest score with the first video and the fifth highest score in the next two videos. Interpreter 3 had the fifth highest score out of six with the first video and then had the sixth highest score in video 2 and 3. Interpreter 4 had the lowest score with the first video and actually improved to the fourth lowest with the second and third video. The second interpreter was pretty consistent across all three videos. These numbers indicate something more than simple fatigue at play in how well interpreters deliver key science words and this needs to be more closely examined.

Table 4 contains the number correctly transcribed key science words, and percent correctly transcribed key science words for five of the CART personnel. One of the six CART participants (C-4) was dropped from the analysis, because only two out of her three transcripts were available for scoring.

Table 4: Number and Percent of Key Science Words Delivered by CART Personnel

Number possible correct key words	Video 1: Seawinds n=751		Video 2: Earth Science n=1,113		Video 3: Data Analysis n=1,279		Mean (SD) across three videos 1047.67 (270.00)	
CART	# Correct	% Correct	# Correct	% Correct	# Correct	% Correct	# Correct	% Correct
C-1	741	99%	1,094	98%	1,241	97%	1,025.33 (256.98)	98.00% (1.00)
C-2	741	99	1,085	97	1,244	97	1,023.33 (257.11)	97.67 (1.15)
C-4	740	99	1,035	93	1,240	97	1,005.00 (251.35)	96.33 (3.06)
C-5	739	98	1,084	98	1,239	97	1,020.67 (255.95)	96.33 (2.08)
C-6	741	99	1,097	99	1,250	98	1,029.33 (261.16)	98.67 (0.58)
Mean (SD) Across CARTS	740.40 0.89	98.80 0.45	1,079.00 25.23	96.20 2.59	1,242.80 4.44	97.20 0.45		

CART participants rarely made errors, and when they did, the errors in translation were usually due to a single word misinterpreted by the dictionary being used. (All five of the five CART stenographers used a legal dictionary, the most readily available to CART captionists regardless of the classroom assignments they may receive.) The largest variability for captionists occurred in Video 2, but this only meant a difference in a couple of words. In the captioning of this video, the stenographers' dictionaries either did not recognize or transcribed incorrectly names or pronouns such as 'El minnow' for El Nino (weather pattern), and 'EK QUA door' for Ecuador (both errors from C-4). Other errors were more scientific terms which would never be seen or used in legal environments, such as 'DRAUTH' for draught (also from C-4).

A two (types of support services) by three (videos) ANOVA was used to analyze the data. For these statistical tests, an alpha level of .05 was used to reject the null hypothesis. The Repeated Measures Analysis of Variance Test (Table 5) revealed a significant main effect for Video, $F(df2) = 84.08$, p = <.0001. The three videos did not contain the same number of key science concepts, nor were they equally difficult to transcribe. There was also a significant main effect for type of support service (Group) $F(df1) = 17.75$, $p = .0023$. For all three videos the captionists demonstrated significantly higher means than the interpreters. In Video 1: Seawinds, the captionists scored very high, with 98.5% accuracy, while the interpreters had an accuracy rate of 81.0%. On Video 2: Our Home, captionists communicated 96.9% of the key words, while interpreters included 80.1%. On the final video Video3: Data Analysis the captionists included 97.2% of the key words while interpreters produced 62.7% of the key words. The number of key science words that CART personnel were able to deliver was significantly greater than the number of key science words that the interpreters were able to deliver. The captionists also had significantly less variability in their scores than the interpreters, indicating that the captionists were more consistent in their ability to provide the key words in each video.

Finally, as summarized visually in the bar plots in Figure 1, there was a significant interaction between Video and Support Service Type (Group), $F(df2) = 15.52$, $p = .001$. The captionists produced a significantly higher number of correct key science words for each of the three videos, but the difference was greater in Video 3 than in the other two videos.

Table 5: ANOVA Table of Mean Squares

	DF	Sum of Squares	Mean Squares	*F*-Value	*p*-value
Group	1	546427.52	526427.52	17.75	.0023
Subject(Group)	9	266923.21	29658.14		
Videos	2	800170.10	400085.05	80.08	<.0001
Group x Video	2	73862.57	73862.57	15.52	.0001
Video x Subject(Group)	18	85646.69	4758.15		

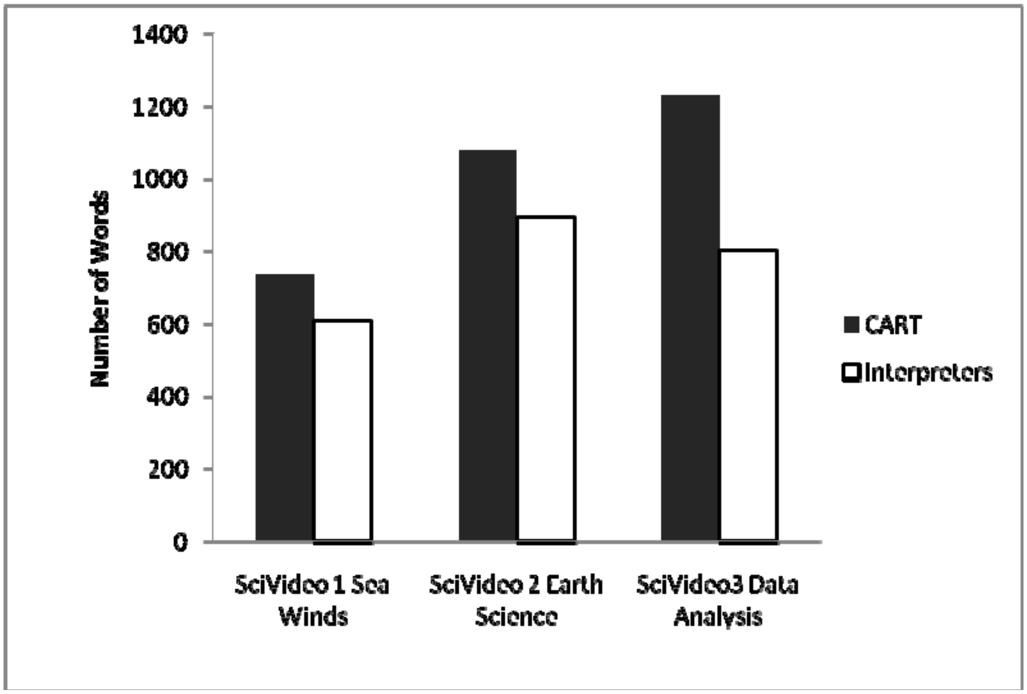

Figure 1: Delivered key words Cart versus Interpreters

5.0 CHAPTER 5: DISCUSSION

This study examined the accuracy of delivery of science information to deaf students through two separate methods of communication, real-time captioning and ASL interpreting.

A significantly higher accuracy of delivery of science content was found by the CART personnel as compared to the sign language interpreters who participated in this study. This section will discuss factors that may have contributed to this difference.

CART personnel demonstrated an overall accuracy of 98 percent in terms of providing key science words while translating the audio portion of science videos on three separate topics. The interpreters demonstrated an overall accuracy rate of 73 percent. One reason for this difference may be in the training that the captionists receive, which is standardized and thorough across the country. In order to become certified in this profession, personnel must meet very specific goals not only in rate of delivery but also in correctness of delivery.

In comparison, interpreters do not receive the same training *nationally* as do CART personnel. There is currently no national standard for training educational interpreters, though many states have established their own guidelines, with the state of Minnesota setting the standard for other states to follow. In order to attain a Certification of Deaf Interpreting (CDI), potential interpreters in Minnesota must pass a written knowledge test and a performance test. The performance tests are rated both by professional interpreters affiliated with Registry for Interpreters of the Deaf (RID) and Deaf/Hard-of-Hearing raters who rate the ASL skills of the interpreters. There are currently 30 states that require certification, but they all require different levels of certification. Some require state certification, some national (RID), and others require Educational Interpreter Performance Assessment (EIPA) which is specifically for education (Schwarz, 2009). This lack of standards may be responsible in part for the quality of interpreting found in this study. Isham (1997) writes that ASL interpreter education lags behind the education of spoken-language interpreters. There is a loss of accuracy of the spoken message in the translation process from English to sign language which needs to be rectified by more formal training and ongoing professional development for interpreters, as well as socialization of interpreters in the Deaf community.

Some 'interpreters' may well be *transliterating* rather than interpreting, and this difference often indicates a difference in training and skills for these service personnel. As stated in the *Routledge Encyclopedia of Translation Studies* by Isham,

> "Transliterating – an overt formed-based approach – appears to to support the mistaken view that interpreting is merely the act of replacing the words of one language with those of another. Moreover, transliterating is, if anything, hampered by the delay inherent in consecutive work and is therefore easier to perform in the simultaneous mode. This, combined with the fact that the general public expects sign interpreting to be *simultaneous*, has led to more transliterating. Another factor is that recent legislation in the United States has made It mandatory that interpreters be provided upon request by any agency receiving federal funds. The demand for interpreters who can serve the deaf community far exceeds the supply, leading to an unfortunate

emphasis on producing service providers quickly." (p. 223)

Third, the drive towards producing and supplying more ASL interpreters may mean that the majority of these personnel lack adequate experience with the Deaf community, and these interpreters tend to use a form of signed English rather than ASL (Isham, 1998). The interpreters in the present study were less experienced than the CART personnel and for this reason they likely made more errors.

Two of the interpreters in this study were uncertified, although one was in the employ by the University of Pittsburgh Disability Resources and Services, and one was in the process of being trained to become an interpreter at the Community College of Allegheny County (CCAC). CCAC has an associate of science degree program in interpreting that is recognized by RID. Programs such as the one at CCAC are becoming more common nationwide because of the increased need for interpreters. Many times school districts will either not find enough certified interpreters available for their students needs, or will use uncertified interpreters because the pay scale is less (Smith, 1999; U.S. Commission on Civil Rights, 2002).

Interpreters who feel they are ready to interpret in educational environments often notify local universities, colleges, and even school districts of their availability. Since these interpreters do not have certification, administrations using them do not have to expend the type of money necessary for interpreters with certification (Virginia Department of Education, 1993). In this way, administrations can follow the letter of the law since neither the IDEA or by Sections 504 and 508 of the 1973 Rehabilitation Act specify standards that indicate level of expertise required by educational interpreters.

Much of the lag time created may have been due to interpreters either searching for correct signs to use for science vocabulary and/or the use of fingerspelling for unfamiliar technical terms. This problem could be solved by increased training in correct science and math signs, and development and use of online lexicons with technical signs such as the one currently being created at National Technical Institute for the Deaf (Methods and Materials for Teaching Science to Deaf Students, 2008). However, Deaf students in public schools need to have signed vocabulary training in science terminology as well, so that they will recognize the science signs used by interpreters. Increased technical sign availability will not succeed in increasing science conceptual learning if the students themselves do not know the vocabulary.

One problem that needs to be more closely examined is what type of errors was made over time. In this study, it was seen that most errors were deletions of words or entire concepts due to lag time. However, part of the reason for creation of lag time was due to the need for interpreters to search for appropriate signs who lacked either experience or knowledge of science concepts and vocabulary. So it needs to be seen that if interpreters were trained in appropriate science sign vocabulary, would lag time decrease? And would this decrease the later errors made over time?

More research needs to be done on whether fatigue of any kind was a problem in the delivery by interpreters, or whether the vocabulary or science concepts of the third video made delivery more difficult.

Another possible reason for the difference in accuracy is the fact that the captionists are conveying exactly the information they receive. That is, they hear the audio message in English and they type and transmit that message in English. In contrast, the sign language interpreters are expected to convert the information heard in one language (English) to a different language, American Sign Language.

The only errors made by CART personnel related to the delivery of correct science terminology. Occasionally, a commonly known word such as ‘hurricane’ was misspelled on the transcript. This was probably not due to the CART personnel’s knowledge of science, but rather points to the need to improve the dictionaries being provided to CART personnel for specific academic disciplines. Most of the personnel worked for lawyers, so the dictionary used by them was predominantly focused on legal terminology. When the captionist typed in a word such as ‘hurricane’ the dictionary would not recognize the word, and it would occasionally produce a word phonetically similar word instead. In Video 2 one CART person typed in the phonetic code for hurricane. On the transcript, because this was not recognized by the dictionary, hurricane came up as ‘U R CANE.’ This was to draw the attention of the stenographer to the need to fix the word, or to add a word to the dictionary. In most cases, when a word was capitalized in such a manner it did not bear any resemblance to the original English science term, and the deaf student would likely struggle to understand what was being said.

Some errors identified on the CART transcripts were the actual phonemes that the stenographers typed into the machine. This happened with the word DRAUTH (drought), which was typed in by the captionist. It was probable that the phoneme for draught should have been DRAUT, which may have then been recognized by the dictionary. The addition of the H created a different phonetic sound that did not match any known words. This indicates a need not only for enhanced resources such as better dictionaries in different content areas, but also a need to train captionists in phonemes for scientific vocabulary.

In regular classrooms, a major difference between CART and interpreting is that at some time after lecture/lesson, CART personnel often give the deaf student a hard copy of the transcript for additional studying. This hard copy is corrected by the CART personnel, and, under most circumstances, errors are spotted and corrected before the transcript is given to the student. So, errors in CART transcripts during a lesson may not permanent, while interpreter errors are never corrected and may be more likely to persist in the students' knowledge base. In this study, CART personnel were not asked to correct their transcripts as it was desired to look at what deaf students would see in the classroom.

One problem that arises with using CART in classroom situations is the demand on reading skills are required to comprehend the captions. It has yet to be determined if and how much real-time captioning improves learning in deaf students (Marschark, Lang, & Albertini, 2002). Previous research with deaf college students showed that understanding captioning of films is dependent upon the reading skills of the students (Hertzog, Stinson, & Keiffer, 1989). Unfamiliarity with the English science vocabulary may prove to be a problem in both captioning and use of CART personnel in a science classroom.

It has long been recognized that if the rate of presentation of reading material is increased the hearing student experiences decreased comprehension (Kieras, 1978; Dyson & Haselgrove, 2000). Dr. Carl Jensema, in his report *Caption Speed and Viewer Comprehension of Television Programs* (1999) brought up this same problem as related to captioning material for deaf learners. He said “Many captioning policies, including the move towards verbatim captioning are not based on research. We need research to determine how fast captions should appear on screen, what presentation rates people prefer and are capable of reading.” In another study with elementary deaf students it was determined that the time constraints involved in captioning caused literacy problems for those deaf students because of the captioning moving quickly off the screen (Jelinek-Lewis & Jackson, 2001), These studies have shown that a trade-off exists between speed of captioning and accuracy whether in hearing or deaf students. Whether CART and interpreting differ in their impact on learning on deaf students, especially with regard to rate of delivery, bears further investigation.

One of the major issues using CART is that the Deaf students are less able to read English at rates conducive to using CART in classrooms. The present study did not examine the comprehension of science by deaf students using CART in *real-time,* and this needs to be researched.

Under most circumstances CART personnel are able to clean up the vocabulary and other errors in their transcriptions before sharing the materials with deaf students. Many deaf, however, have expressed concern that the CART printout of the entire class session is unwieldy and not as useful as notes taken by manual notetakers because no special emphasis is indicated on which information is important to know. Current CART software is not capable of highlighting the important concepts from the class. It is paramount to take into consideration the linguistic skills of the student, whether English or ASL is their primary language, and their reading skills and the rate at which they can read. Whether transcripts that are provided by CART personnel are more valuable than notes taken by a notetaker in the classroom also needs to be investigated.

It would appear that it is wrong for the schools or the school districts to believe that by provide an interpreter or CART personnel to deaf students, and then consider that they have provided equal educational opportunity to these students under the law. Ultimately, the proof of equal opportunity for deaf students in regular schools will lie in whether these students successfully learn the same information that their hearing peers learn, as well as the deaf students' performance on standardized tests in science and math.

5.1 Limitations

In Table 2 of the results it was observed that the CART personnel showed significantly less variability than the interpreters in their delivery of the key words. This may be related to the limitation in this study concerning the quality of and availability interpreters and CART personnel. While CART personnel in this study were highly accurate, in general there is a very low availability of trained captionists for education. Likewise, the interpreters selected for this study may or may not be representative of the pool available in other educational districts around the country. The size and the communication needs of the deaf population being served in any particular school district may influence the supply of CART, sign language interpreters, or both. As the demand rises, often the supply of quality human resources will rise.

Whether an area includes a deaf residential school may also influence the need for different support systems in nearby public schools. Pittsburgh has a relatively small deaf community, most of whom are deafened congenitally or in early childhood. Currently, interpreter availability is adequate to provide for the few deaf students in each of the school districts, without having to rely upon court stenographers. There is access to a quality residential school for the deaf, which requires that both its teachers and staff use sign language. There is also a Catholic school, DePaul, to which some deaf and hard-of-hearing students from the Pittsburgh area are sent whose curriculum is based on the practice of oralism. There is a program to train interpreters for use in educational circumstances that is nationally recognized by the national Registry of Interpreters of the Deaf and the National Association for the Deaf, and current efforts are underway by these two organizations to codify what defines a qualified educational interpreter.

The results of this study may be different in comparison to other areas of the state or country. There is great variability in skill levels and experience among interpreters and captionists. Some areas will put more emphasis on using interpreters because of availability, while other areas will concentrate on using captionists in public schools. This local preference will lead to more experience in educational interpreting or more experience in educational captioning, which will have an impact on the skill, vocabulary, and concept awareness by these professionals. Additional studies, similar to this one, would need to be conducted in different cities, and with larger numbers of participants, to build the knowledge base needed to generalize about the accuracy of these two support systems delivery approaches.

Another limitation with respect to interpreting, one that may influence the accuracy of key words as measured in this study, is the lack of availability of technical signs for many science terms. An estimate has been made that fewer than 50 percent of key science words have equivalent technical signs for use in instruction on the high school level (Lang, 2009). Some examples of science terms for which technical signs were unavailable in the present study were CALVING and REMOTE SENSING. Most of the interpreters would then resort to fingerspelling which is appropriate, provided students have the ability to learn through fingerspelling in this manner. With the term CALVING a student may not understand the meaning of the term as it applies to meteorology, and instead assign to it the usual meaning of a cow birthing calves. As stated previously in this paper, fingerspelling relates to the reading ability of deaf students similar to that of reading text. Additional research is needed to better understand how much deaf students understand when a term is fingerspelled as compared to signed. Research has shown, for example, that terms that are signed with single signs are recalled significantly better than terms represented by compound signs (several signs combined) and those terms that are fingerspelled (Lang & Pagliaro, 2007). Another issue for interpreters is that in spite of the increase development of technical signs in science, many interpreters may be unfamiliar with these terms, and so will fall back on fingerspelling which can increase lag time.

The way that this study was coded for key words may need a second look to determine how the delivery of those words and the absence of those words may impact the understanding of the concepts. In order to more fully understand how science vocabulary impacts cognition, it will be necessary to use the information from the present study with Deaf students. Does the emphasis on key words need to be changed to key science concepts, and if this is done, does that impact the amount of correctly delivered concepts by interpreters? And will this directly impact the amount of concepts that Deaf students retain? These questions need to be looked at.

6.0 CHAPTER 6: CONCLUSIONS

Whether or not real-time captioning or interpreting is used to provide science information to deaf learners in the classroom, research is needed on the advantages and disadvantages of each approach for students at various age levels, reading levels, and with regard to content that may place different cognitive demands on the learner. Adults can often retain some control of their situation of observing the interpreters or reading the transcriptions through self-advocacy, whereas deaf students within a public school classroom may be constrained by inexperience and self-esteem problems.

A significant body of work has been compiled on reading and deaf students. There has not been as much research into the problem of conceptual delivery through support services. This is important for deaf students placed in public schools, and the schools that are then required to provide informational access.

Deaf students have multiple demands on their visual attention, and this becomes even more prevalent in public schools. Unfortunately, unlike hearing students who can look at something else while the teacher is talking and still hear what the teacher says, if deaf students turn away from their interpreters to look at anything including the teacher or a film, they may miss some of the science that is being taught. The interpreters cannot request that the teacher stop and restate what was said for the sake of a deaf student who may have missed something due to the need to pay visual attention to many things at once. Even if the interpreter does notice that the deaf student has missed information, the science teacher cannot stop for the sake of one student in a classroom. Consequentially, a deaf student may become frustrated over frequently missing new science information because of the multiple visual demands.

Due to all these visual demands, deaf students may also experience eye fatigue. Many instructors' handbooks recommend that teachers allow for strategic breaks to relieve eye fatigue of the student and hand fatigue of the interpreters (Ohlone College, 2009). This may also be needed for students watching captions for long periods of time, and this needs to be researched in the future. There needs to be awareness training through faculty development for teachers in public schools to better understand the issues their deaf learners face, and how to facilitate learning through more active involvement by deaf students. Teachers also need to be taught sensitivity to the multiple visual demands placed on deaf learners, and given ideas on how to lessen the stress of those multiple demands by providing notes or perhaps taping classes so deaf students can peruse them later at their convenience.

Future studies will need to examine the extent of learning which occurs through caption versus interpreters. This will more fully elucidate what these students need in public school classrooms to perform on par with their hearing classmates. It will also be helpful to learn whether two different modalities of conveying science information simultaneously, such as CART *and* sign interpreters, would enhance understanding. This may be similar to a multimedia presentation which cognitively primes "two qualitatively knowledge representation systems in learners – a verbal channel and a visual channel" (Mayer, 2005, p. 448).

The major finding of this study is that there is a substantial and significant difference in the accuracy of the science information provided by the two primary support communication support service for deaf students enrolled in public schools. Though this needs to be further researched in other metropolitan, suburban, and rural areas with different steno-captioning methods, the findings of this study may be very important in determining which support services best meet the needs of deaf students. More research needs to be done on the impact of incorrect delivery of secondary vocabulary (such as “in” instead of “on”) in both interpreting and captioning, and how that impacts learning of science concepts.

Future research should not concentrate just on inclusion of a larger N, or population of interpreters and captionists, but rather look at the variability in training and experience, and what happens when the order of the videos are changed or the science content of the videos are changed. The length of interpreting assignments and how fatigue impacts delivery should also be studied as related to the measure of key science words included in translations.

Research needs to be done on how deaf students learn with use of these different support services, and whether deaf learners do better when *THEY* also know the technical signs. The impact of lag time on learning also needs to be looked at, as well as how the incidental science information attained by deaf students outside of schools creates enough of a knowledge base for them to build on. Would increased exposure to science information in the home and at places such as museums aid in the formal learning of science concepts in schools by deaf students?

Current literature demonstrates that inclusion of deaf students in public schools does not automatically guarantee equal access to educational opportunities for these students. It is critical to continue to build a base of knowledge through educational and psychological research in order to enhance learning of deaf students in science classrooms. Hopefully further research will lead to improved test scores for deaf learners and performance that is more comparable to that of their hearing classmates. The quality of ASL interpreters in the classroom continues to be of great significance. This study demonstrates a significant variability in level of information made available to deaf students by sign language interpreters. As stated by Marschark et al. "The impact of educational interpreting on achievement is just now being explored, and initial results raise questions about both its effectiveness compared to text alternatives and how both support services mesh with student communication skills” (2006, p. 422).

As far as possible the support service should match the needs of individual students with deafness, providing him or her with the highest level of access to classroom events and discourse. Advances in technology such as CART may improve accuracy of transmission of science information to deaf students. The findings of this study demonstrate that CART personnel may provide more complete and more accurate level of information in the science classroom than interpreters may be able to, but whether deaf students learn more effectively through captioning remains to be studied.

The success of education of deaf students in public schools is dependent in a large part upon both the quantity and quality of support services. If the quality of the training provided to support service personnel is limited, so will the quality of the education that these students obtain.

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APPENDIX A

CIVIL RIGHTS ISSUES IN WEST VIRGINIA

Chapter 3

Treatment of Racial Minorities and People with Disabilities in the Public Schools

Noncompliance with Federal and State Laws on Special Education

Panelists detailed various ways in which state and county educational authorities in West Virginia have failed to comply with key federal statutes on disabilities. These include (1) Section 504 of the Rehabilitation Act of 1973,6[33] which prohibits discrimination against persons with a disability by any recipient of federal financial assistance; (2) the Individuals with Disabilities Education Act, or IDEA,7[34] which entitles children with disabilities to a “free appropriate public education” in the “least restrictive environment” and based on an “individualized education program”; and (3) the Americans with Disabilities Act of 1990,8[35] the key statute outlawing discrimination against people with disabilities in many aspects of public life.

Reed Martin, a Morgantown attorney who has practiced special education law in various states for 28 years, said, “West Virginia ranks as low as any state I have ever seen in terms of compliance” with the IDEA and Section 504.9[36] He based his statement on interaction with more than 1,000 parents in West Virginia over the preceding year, and on the responses his office has received to numerous complaints filed with county, state, and federal agencies.10[37]

The school system in Monongalia County, which includes Morgantown, was specifically criticized at the forum. Kent Bryson, a staff attorney with West Virginia Advocates,11[38] cited a monitoring report by the West Virginia Department of Education that found the Monongalia County schools out of compliance with IDEA in several respects.12[39]

Barriers for Hearing-Impaired Students

Two points were made: deaf children may suffer from isolation in mainstream classrooms, and sign language interpreters working in classrooms often lack the necessary proficiency.

Isolation of mainstreaming.13[60] Federal special education law was first designed in the 1970s to place disabled children in regular classrooms, which were thought to provide the "least restrictive environment," but in 1997 the law was changed to recognize the special needs of the hearing impaired, for whom a specialized instructional setting may be less restrictive.14[61] Nonetheless, the vast majority of deaf students in West Virginia are still educated in regular public school classrooms with sign language interpreters, and several panelists spoke about the isolating effects of this mainstreaming.15[62] Ruby Losh, a disability rights advocate, noted that there is no direct communication between the mainstream teacher and a deaf student:

There is only communication between the interpreter and the student. The teacher is talking to the student and there is a classroom interpreter, but the teacher may not know what is going on between the interpreter and the student. . . . So it is an inclusion program, [but] it is isolating the deaf student in a lot of ways.16[63]

By contrast, at the state school for the deaf located in Romney, all teachers and staff know sign language well; students can communicate freely with everyone around them, and the instruction is accessible. However, panelists suggested that the state does not want to publicize the services offered at Romney and that there are barriers to expanding the school.

Interpreters' proficiency.17[64] Ms. Losh noted that West Virginia does not require certification of American Sign Language (ASL) interpreters who work in the public schools,18[65] and she said schools often hire uncertified, poorly qualified interpreters because they are cheaper than those fully qualified.19[66] Only three of the 10 interpreters in the Monongalia County schools are certified.20[67]

There are not enough qualified interpreters in West Virginia to serve the state's approximately 2,000 hearing-impaired children in mainstream classrooms.21[68] Only one institution, Fairmont State College, trains ASL interpreters. According to Dolly Ford and Teresa McGonigle, sign language interpreters at the Morgantown forum, the two-year program at Fairmont is not sufficient in itself to produce highly qualified interpreters.22[69] They said that there is demand among hearing students in elementary-secondary schools to learn ASL as a foreign language, but that the public schools do not offer it.23[70] The interpreters at the Morgantown forum called for elementary-secondary schools to offer ASL as a foreign language so that potential interpreters could begin developing proficiency early.

APPENDIX B
INTERPRETER BACKGROUND/EXPERIENCE SURVEY

INTERPRETERS

Background and Experience Survey: (Please check one answer.)

1. **I am a certified interpreter (RID certification- CDI): ___ Yes ___ No**
2. **I have interpretation experience of:**

   6 – 12 months ___

   Over 1 year ___

   Over 5 years ___
3. **I have achieved the following postsecondary degrees: AS (2 years) ___**

   BS (4 years) ___

   > 4 years ___
4. **I took the following classes in high school: (Check as many that apply)**

   Biology ___

   Chemistry ___

   Physics ___

   General Science ____
5. **I took the following science classes in college: (Check as many that apply)**

   Biology ___

   Chemistry ___

   Physics ___

   General Science ____
6. **I received special training in educational interpreting:**

   Yes ___ No ____
7. **If yes, clarify if I had special training in science interpreting: Yes ___**

   No ___

8. **If yes, I have had previous experience interpreting in science or medical situations:**

   Yes ___

   No ___
9. **In which of the following activities do you engage: (Check as many that apply)**

   Read daily newspapers _____

   Read science journals like Discover, Scientific America ______

   Watch educational or public programming on PBS, Discovery Channel, The Learning Channel, etc. _____

   Read books ______

See movies _____

Go to museums _____

Attend deaf social activities _____

APPENDIX C

CART BACKGROUND/EXPERIENCE SURVEY

CART PERSONNEL

<u>Background and Experience Survey</u>: (Please check one answer.)

1. I have the following certification (Please check all that apply):

CSR- Certified Shorthand Reporter (state certification) ___

RPR-Registered Professional Reporter (NCRA) ___

CM or RMR- Certificate of Merit or Registered Merit Reporter ___

RVR-Realtime Verbatim Reporter (NVRA) ___

CRR-Certified Realtime Reporter (NCRA) ___

RDR-Registered Diplomate Reporter (NCRA) ___

2. I have transcription experience of:

6 – 12 months ___

Over 1 year ___

Over 5 years ___

3. I have achieved the following postsecondary degrees: AS (2 years) ___

BS (4 years) ___

> 4 years ___

4. I took the following classes in high school: (Check as many that apply)

Biology ___

Chemistry ___

Physics ___

General Science ____

5. I took the following science classes in college: (Check as many that apply)

Biology ___

Chemistry ___

Physics ___

General Science ____

6. I received special training in CART for education: Yes ___

No ____

7. I received special training in using CART in science or medical situations:

Yes ___

No ___

8. I have had previous experience interpreting in science or medical situations:

Yes ___

No ____

9. In which of the following activities do you engage: (Check as many that apply)

Read daily newspapers _____

Read science journals like Discover, Scientific America ______

Watch educational or public programming on PBS, Discovery Channel, The Learning Channel, etc. _____

Read books ______

See movies _____

Go to museums _____

Attend deaf social activities _____

APPENDIX D

Interpreter/CART Consent Form

Interpreter-Participant Approval Form

The purpose of this study is to determine the type of science information delivered by interpreters in a public classroom situation in which a videotape is used. Since only about 9% of all deaf students are currently in residential schools for the deaf according to a recent report by the U.S. Department of Education (2000), it is obvious the need for interpreters in the public schools is intensifying. Most research on deaf students and learning has been done in residential school situations, there is a great need to find out how communication of science concepts through interpreters (rather than directly from the teacher) may impact the understanding of those science concepts by deaf students.

There is also a concurrent push to use Computer Aided Real-Time Transcription (CART) in the classrooms instead of interpreters. In some areas of the United States, such as rural areas of West Virginia, the ability to find certified and qualified educational interpreters is severely limited. In some of these situations, there will still be courtroom stenographers available to use in educational situations as well. However, there has been almost no research into the impact of how well CART conveys and delivers science information to deaf students, especially given the knowledge that many deaf students have reading difficulties, and the normal speed of CART transcription is 225-250 words per minute.

So it becomes essential to first find out from these currently used communication types and personnel, exactly what is delivered to deaf students in science classrooms. In this study, both interpreters and CART personnel will be shown 3 15-minute segments of NASA CORE videotapes that they will be asked to interpret and transcribe, respectively. In the case of the interpreters, they will be videotaped, and those videotapes will be reviewed by both me, the primary researcher in this case, and a science teacher from Western PA School for the Deaf. This is necessary because though I have the science background, ASL is my second language (not my primary one), and I need to have someone who uses ASL on a daily basis in a science classroom. CART personnel will be given floppy disks that I will retrieve immediately after the sessions (so they will not be able to correct any mistakes).

The aim of this study is to get a broader understanding into the communication modes used in public school science classrooms with deaf students. The information in the videotapes of the interpreters will be counted for number of correct words delivered (as will as the CART transcripts). A small questionnaire concerned with background, experience, and training will be given to both interpreter and CART participants, but in **no case will names** be used or mentioned. Nor will these videotapes be shown to other people besides the two mentioned and the doctoral committee (if necessary). **All information will be done with complete anonymity to interpreters and CART personnel.**

I, ____, agree to participate in this research study. I am assured that no additional duties or requirements will be asked of me other than to interpret 3 segments of science videotapes in the manner I am best able to convey and deliver this information. I also understand that my anonymity will be preserved in participating in this study.

______________________________________ ______________

(Signature) (Date)

APPENDIX E

Transcripts of CONNECT Videotapes

NASA CONNECT Video Series – Video 1

Sea Winds: Catch the Wing: The QuikSCAT Story

When you want to understand what's happening on the planet Earth, you really want to understand the interplay between the oceans and the atmosphere.

And the interplay of those two controls our climate.

If you want to understand major phenomena like El Nino, it's crucial that you understand the winds.

Why?

Because, very simply put, winds drive the ocean.

One of the major reasons that we can't predict the weather tomorrow is that we don't know what the weather is today.

We don't know what the weather is today because seventy percent of the earth is covered by the ocean and there are actually very few weather measurements that are made over the ocean.

The science community has to go to the engineers and say can you possibly think up a brilliant way of getting us weather measurements over the ocean?

The issue that we gotta discuss right now…

My name is Phil Graf and I'm the project manager here at JPL.

Working at JPL is extremely exciting.

You get a chance to be challenged by problems that have not been solved before…

Without problems, we wouldn't need engineers.

And what people like me get paid to do, is solve problems.

We're sending a measuring device into space to understand the climate of the earth better

and for helping us better predict the weather to save lives.

We'll be able to tell people where the winds are blowing and how they're blowing.

Blowing this fast. Moving in this direction.

All of this is helping us to understand the world that we live in.

Taking measurements from space we can get accurate and frequent measurements with the scatterometer.

The way the scatterometer works is, it is a radar that sends out a beam of radio energy to the ocean's surface.

As the wind passes over the ocean's surface, it roughens it.

It makes little wavelets. Very small-scale waves, with wavelengths on the order of the length of your thumb.

They pop up very very quickly, and the way that the scatterometer actually measures wind speed and direction is by bouncing radar beams of these short waves.

As the wind speed increases, the ocean gets rougher and rougher, more turbulent.

The rougher the surface, the more back-scatter we get into the antenna.

If you have a storm coming, I don't know of anybody that wants to sail into that storm and take measurements and try to track it, but we will be able to track it from space and not get anybody in harm's way.

NASA developed a NASA Scatterometer known as NSCAT.

In 1996, NASA, along with its Japanese counterpart NASDA, launched the ADIOS spacecraft and onboard we had the NSCAT instrument.

That instrument operated for about 10 months.

It took a phenomenal amount of data far beyond anything we even envisioned.

After the launch, we worked very very hard through June 30th, a date that's seared into all of our memories.

One day I was, you know, doing the regular daily analysis and I noticed that a couple of parameters had way exceeded their limits.

There was some really funny stuff.

I didn't know exactly what was going on and I showed it to other people.

Um, you know, I don't see anything.

All of a sudden power had shut down.

There was a spacecraft failure, not an instrument failure.

But a spacecraft failure and we lost that data stream.

Well, we lost it.

Of course, we were all devastated professionally and personally as well.

…the Fasttrack program and it was put together as the result of our NSCAT loss.

We gathered up the support, funding, etc. and pulled together a recovery mission.

I'd say, in the words of Homer Simpson, 'oh what a glorious day.'

NASA management and congress commissioned us to go ahead, and we call that mission QuikSCAT.

Now the purpose of the QuikSCAT mission is to take a seawinds instrument and get it back up in orbit as quickly as possible.

If we were proceeding on a nominal schedule right now, the QuikSCAT mission would take us about 3 years, but because of the urgency, we're attempting to do it in one year.

That's an incredibly ambitious schedule, given the complexity of the instrument itself.

Scatterometer instrument consists of 3 subsystems,

has an antenna subsystem,

a command and data subsystem,

and a radar/electronics subsystem.

It takes all 3 elements to play together and to work together as an instrument.

There's an instrument and then there's the spacecraft that carries the instrument.

This is a mock-up of the QuikSCAT spacecraft.

If we launch the instrument without the spacecraft, the instrument has no ability to generate power.

The instrument has no ability to determine where it is in space.

The spacecraft provides all those resources.

And on QuikSCAT we are building a science instrument.

And BALL Aerospace, our contractor, is building the spacecraft.

We have people working around the clock, building the spacecraft.

I'm Cary Ludtke.

I'm the program manager for the QuikSCAT program here at BALL.

I'm responsible for delivering the spacecraft.

I'm Karen Cramer.

I am one of the systems engineers.

I'm working with Ball Aerospace.

We're trying to make sure that when we put this whole package together, it works.

Put your home computer on a spacecraft and launch it.

As its going through the atmosphere, it's subjected to tremendous forces and it will probably never turn on and it would sort of fall apart.

We spend a lot more time making sure that the components of computers we fly meet very tight specifications because if they fail, we can't go up in space and pull that board out and replace it with another like you can do here on earth.

So we do a lot of testing to make sure it works.

And there's your response. Looks good.

We're up here trying to vibrate this to shake it to make sure that everything is together the way it's supposed to be, and make sure we're not going to break anything when we launch it.

Stop.

But if we break it here, we have a chance to fix it.

If we break it in a launch, all bets are off.

We won’t be able to get to it. We won’t be able to fix it. It’ll be flying around the earth broken.

Z access (axis) on TWTA (tripped us off in) for the overload. [Note: Not only was the word axis spelled as ‘access’ by the captioning company-NCI-but NASA missed it! Also, ‘tripped us off in’ was not captioned. Major errors.]

There may be something loose in that box.

We’ve gotten a couple of funny responses in here.

We’re trying to figure out whether to open it up and figure out what the problem was and fix the problem.

It seems to me that opening this thing up is a big deal.

We kind of want to avoid pulling covers off of this thing because it is a long process.

We’re in the head-scratching mode right now.

We had to decide whether this was something we had to fix or whether it was something that we could live with.

On 3…1, 2, 3.

Keep going, that’s good.

My name is Patrick Wu.

I am the thermal design engineer for Quikscat.

My job is to make sure the instruments maintain certain temperatures,

just like human bodies and also make sure that nothing got damaged if the temperature gets too hot or too cold.

Thermal vac testing is basically you put the instrument in a so-called space/light environment.

We pump all the air out of the chamber, and keep the device up and cool it down to find out whether the hardware can handle the temperature extremes.

So we can be sure that the instrument will work.

That process went quite successfully.

I’m pretty confident we have a very good design for this project.

We've gone through vibration testing.

We've gone through thermal testing.

All the testing's supposed to be done.

We're supposed to have confidence in this unit.

And here we are 3 weeks before pre-ship review.

So we're supposed to be done with this thing.

But yet we've got this electrical problem we don't understand.

There's a lot we can do to understand this and see if there's a solution.

We're going to have to do something about it.

We just can't assume it's going to go away.

If it looks like that's a catastrophic thing, we have to pull it out.

And you can take the easy way out and say go pull the thing.

That's an awful lot of work.

This is what I'd like to do.

The decision we made was to open up the radar electronics box.

Over here, and take a few covers off and examine this.

We brought it into this clean room and we'll examine it for potential damage.

And we're talking about…unfortunately…realistically, probably weeks of work.

The problem that we had was kind of a minor electrical problem,

and we were able to come up with some sort of a fix for it, and get it back together, and get it tested.

We figured out a minimal set of re-tests.

So it took us about a week to recover from this.

We were able to pull it off successfully about a week before pre-ship review.

It was really quite amazing to me.

At the time, I was pretty well stressed and so now, of course, I’m happy we decided to fix all that.

Everybody has pulled together to make this work.

Stop.

There’s been a lot of work to do and a lot of people to put these three subsystems together.

We’ve had people really go the extra mile to get it done on time.

And we’re able to ship the unit out on schedule.

NASA CONNECT Video Series – Video 2

Earth Science Our Home: Earth From Space

El Nino is an ocean event that has far reaching consequences.

The disruption of ocean atmosphere systems affects weather around the globe.

It usually increases rainfall across the southern U.S.,

often causes flooding in Peru and

drought in the west Pacific which can lead to

devastating brush fires in Australia.

El Nino means “The little boy” or

“Christ Child” in Spanish.

It originally referred to a warming of the ocean waters along the coast of Ecuador that occurs around Christmas every year.

Now the term is used a little differently, referring only to much larger warmings that occur across the entire tropical Pacific Ocean.

And not necessarily arriving at Christmas time.

During normal years, the trade winds blow from east to west across the tropical Pacific.

These winds cause warm water to pile up in the western Pacific.

So the sea surface is about 5 feet higher in Indonesia than it is at Ecuador.

The sea surface temperature is about 14 degrees Fahrenheit warmer in the west with cooler temperatures off the coast of South America.

This colder water is high in nutrients, providing food and excellent conditions for growth of ocean plants.

They, in turn, are food for sea animals to eat.

Now, during an El Nino, the trade winds weaken and can even reverse direction in the central and western Pacific.

This, in a sense, shuts off the natural air conditioning by preventing the colder, nutrient-rich water from upwelling.

The results are a rise in sea surface temperature along the coast of Peru.

These waters aren't as nutrient-rich as the colder waters.

And this starts an adverse reaction that moves all the way up the food chain.

Without nutrients, the plants don't reproduce.

So there aren't enough of them for the animals to feed on.

Or it can force animals, fish, and birds to migrate to other areas in search of food.

This can cause imbalances in the food chain in new areas.

This is what happens in the ocean, but the spin-off effects of El Nino alter the weather over land,

bringing heavy rains and flooding to some areas,

and severe drought to others.

With either of these situations, the food chain is thrown out of balance.

Whenever nature is altered in a dramatic way, human lifestyle is also altered.

There is evidence of food shortages world wide during recent El Nino events.

Also, this and other viruses, as well as allergies to certain molds and pollens increase significantly during El Ninos.

You can see how important it is to be able to predict an El Nino.

Satellite technology is one tool that nations around the world are learning to use to help them prepare for El Nino and its effects.

Ray that was a great overview.

But what does that have to do with an increase in volunteerism?

Ahh.

That's a great question, Danielle.

Sometimes, you have to try thinking outside of the box.

Give it a try.

Okay, let me think.

You talked about the changes in the ocean during El Nino and how that affects the food chain.

I'm supposed to connect that to a greater need for volunteers at sea mammal aquariums.

I've got it.

With alterations in the food chain, there must be more distressed sea mammals.

Right.

So it takes more people volunteering for rescue and rehabilitation of sick or stranded animals.

These are major connections.

Look beyond the obvious.

Okay.

I see what you're doing.

You mentioned that a natural phenomenon like El Nino might increase the occurrence of certain diseases.

Right.

Go on.

Well, glacial ice may also be connected to some of the same diseases.

You mean like, glacial ice might be connected to mosquitoes?

Ice and mosquitoes—good connection Ray.

Check this out.

Glaciers exist on all of the continents except Australia.

Mountain glaciers, in particular, are indicators of climate change.

Accumulation of snow and ice are called input, increasing the mass of the glaciers.

Melting and calving, which is when a big chunk of ice breaks off the main glacier are known as output.

And it decreases a glacier's mass.

Many things affect the balance between input and output.

For example, temperature, precipitation, humidity, wind speed, slope, and reflectivity are all factors that can affect this balance.

So, as climate changes, the relationship between input and output also changes.

But most glaciers are more sensitive to air temperature than to any thing else.

You've heard of global warming?

This is a global increase in temperature

that many scientists believe is caused by an increase in heat-trapping gasses in the atmosphere.

These gases are sometimes called greenhouse gasses because they trap heat in the atmosphere.

They trap heat in the atmosphere just like the glass in a greenhouse keeps the heat inside the greenhouse from escaping.

Some of this increase in greenhouse gasses is probably natural.

But some human activities seem to be enhancing the effect.

For instance, through fossil fuel use,

an increase in the release of heat-trapping gasses

could lead to global warming which, in turn,

could lead to glacial melting and there is evidence of melting.

Data suggests that since 1850, some alpine glaciers have lost between 30 to 40% of their surface area.

And about 50% of their volume.

Similar findings have been reported in other glaciers around the world.

Global compilations have shown sea levels have risen about $1/10^{th}$ of an inch per year.

That may not sound like a lot, but by the year 2100 sea levels may rise by almost 2 feet if this warming trend continues.

Ice serves many functions.

During the arctic winter, the air is colder than the water.

The ice helps to insulate the water from the atmosphere.

Where there is no ice, there is a huge heat flow from the water to the atmosphere,

which causes the air temperature to go up.

Ice also restricts the energy of the wind from causing waves near the ice.

That’s why ships often stay near the ice where the seas are calmer.

Ice also acts as a mass exchange,

preventing ocean water from evaporating into the atmosphere

and since ice is white it reflects the sun’s energy, keeping the system cool.

Without ice the temperature of the earth would likely increase, perhaps significantly.

Even a modest rise of 2 to 4 degrees Fahrenheit could have a profound effect.

Some regions of the world might experience more rainfall, leading to floods that would impact agriculture and forest growth.

Fertile wetlands could be lost due to rises in sea level,

and low lying areas might experience flooding from melting water run-off.

Warmer temperatures in the moist areas of the world could become fertile breeding grounds for mosquitoes and other disease transferring organisms,

so we could see malaria in areas of the world where it never before existed.

But you know, Danielle, there are lots of things we could do everyday to help protect us from global warming.

All those things can make a difference, but the best way is to cut down on use of fossil fuels.

You can carpool…bike…walk…use public transportation.

And, plant a tree.

They absorb a lot of carbon dioxide—

one of the greenhouse gases.

And like you said before, look beyond the obvious.

Sometimes even the smallest things can make a difference.

So far we've checked out a natural occurrence like El Nino and global warming.

We've seen how El Nino can affect increased precipitation in some areas,

and how both phenomena can relate to flooding and even drought.

And that's what we're going to look at next—drought and its connections.

You're probably wondering why we're standing in front of a wall of water when we're getting ready to talk about such a dry subject.

But then again, you are probably looking beyond the obvious.

Drought, like other phenomenon in the Earth System, has obvious local impacts.

The most famous dry period in United States history is the 1930's drought in the Great Plains.

That area was referred to as the Dust Bowl

and the drought lasted a decade.

It is estimated by the end of the 10 years span, financial assistance from the government may have been as high as 1 billion in 1930's dollars.

But drought causes more than economic devastation.

It produces a complex web of impacts that can touch our lives environmentally and socially, as well as economically.

Drought increases the risk of fire.

During recent droughts, we've seen the destruction of forest land, wildlife, and homes.

Satellite imagery shows the

far-reaching effects of the soot and ash from these fires, as they get caught up in the winds.

Fires have an impact on air quality thousands of miles away.

There are other ways that the atmosphere spreads the effects of a local event.

For example, take a human initiated activity like…cattle farming in Africa.

Due to overgrazing, there's more dust produced.

Add to this a drought, possibly linked to a change in the weather as a result of say…El Nino.

. Now you've got dust on top of dust!

When the winds blow, dust from Africa gets caught in the Trade Winds and blows westward over the Atlantic Ocean.

This dust has been found in the Caribbean, and is considered a leading suspect in the death of sea fans in the coral reefs.

If you look beyond the obvious.

You know, there's another phenomenon that starts in Africa and affects the Caribbean and the United States.

Let me guess.

You wouldn't happen to be talking about hurricanes now would you?

The wind in this hurricane simulator reaches up to speeds of 85 miles per hour.

That's as much as a class 1 hurricane.

I don't know about you, but I'd much rather see hurricanes from up above.

Come on, let's get out of here.

Most tropical hurricanes have their beginnings in disturbances known as African Easterly Waves, since they originate over North Africa.

The waves are convectively active, that is, they usually contain thunderstorms.

As they move west across the Atlantic Ocean, some of them grow into hurricanes across the summer.

The hurricane season lasts from June to November.

During strong El Ninos there are practically no hurricanes.

In order for hurricanes to develop, the thunderstorms or convective areas, need to reach high into the atmosphere, as high as ten miles.

One of the effects of El Nino is to displace the very fast moving air, known as the jet stream right over the areas where the hurricane usually develops.

We talked a lot about some of El Nino’s bad consequences, but it does have its good points.

Limiting hurricanes in the Atlantic is one of them.

And so we’ve come full circle.

El Nino, a Pacific Ocean phenomenon affects events far away

like hurricanes in the Atlantic Ocean

and drought in Africa.

But if you think about it, that’s the case in everything we looked at today.

I think the message is that all parts of a system are connected in obvious and sometimes not so obvious ways.

And the impacts can be direct, or not so direct.

Like during El Nino, less farming occurs in South American along the equator due to less rainfall.

So the farmers that usually tend to crops have to find another line of work so that they can take care of their families.

These temporarily out of work farmers have to turn to clearing back rain forests to make way for expanding farms.

They clear the way by burning back the forests,

entering more smoke particles

and carbon dioxide into the air.

It’s clear there are major connections all around us.

You just have to look beyond the obvious.

NASA CONNECT Video Series 2000-2001 – Video 3

Program 4: Data Analysis and Measurement: Ahead, Above the Clouds

Timing: From 2:54 to 15:54 on the tape

First, let's learn more about hurricanes.

A hurricane is a violent tropical storm with damaging winds

and torrential rains.

Hurricanes can form in the Atlantic, Pacific, and Indian Oceans.

Hurricanes are given other names in other countries,

such as typhoon in Southeast Asia,

a baguio in the Philippines,

and tropical cyclones in Australia.

How does a hurricane form?

A hurricane gets its energy from the warm moist air at the ocean's surface.

As this air ascends to form clouds

more air is drawn into the hurricane.

Winds spiral upward and we begin to see the familiar shape of a hurricane.

At the center of the hurricane the air descends, forming a very quiet eye with a ring of clouds surrounding it.

The weather in the eye is much different from the weather surrounding it.

The winds grow calm

and the sky may clear.

Surrounding this eye are

bands of heavy rain

and very high winds.

When a hurricane comes ashore

it brings high waves,

severe flooding,

and wind damage.

Hurricanes uproot trees, smash buildings, and destroy power lines.

Hurricane Andrew was the third strongest hurricane to strike the United States coastline

on record.

Andrew swept through Southern Florida and Louisiana in 1992, causing over 25 billion dollars in damages.

Amazingly, few people were killed despite the widespread destruction.

When we want to know if a hurricane is going to affect us we turn to meteorologists.

Meteorologists are scientists who study the causes of weather, like hurricanes, and try to predict where they will go after they've formed.

More accurate forecasts will help to prepare people well in advance of an approaching hurricane and in turn help save lives.

For more on how meteorologists predict hurricanes we came to the Weather Channel here in Atlanta, Georgia.

Well Jennifer, in order for meteorologists, like me, to predict hurricanes we need to know first at least 4 variables.

Temperature,

moisture,

air pressure,

and the most important, wind.

Wind, directly or indirectly, causes all the damage from a hurricane.

For example, winds produce waves which cause flooding.

Anyway, the winds in and around a hurricane that push it along and produce its motion are called steering winds.

Steering winds control three things: The speed at which the hurricane will move,

where it will move,

and whether it will strengthen or weaken.

Well, Dr. Lyons, it seems to me then if you know the information on the winds

then you can easily predict what a hurricane can do.

Winds are important, but remember I also have to look at

temperature,

moisture,

and air pressure.

Ok, all right, so where do you get all that information?

We, here at the Weather Channel, receive data from weather stations on the ground,

from ships and buoys at sea,

from aircraft that fly into the hurricane, like the

Hurricane Hunters,

and from satellites in space.

Because our atmosphere is made up of many layers ideally,

data should be collected at all the different heights or altitudes in the atmosphere.

Therefore, we rely mostly on airborne variables at different altitudes.

So once you receive the data on temperature what do you do with it?

I analyze it.

Along with the data I receive, I look at previous data

and how it is changing with time.

I use my experiences with past hurricanes to predict the hurricane’s strength or its intensity

or its projected path.

Computers at the National Weather Service in Washington DC receive these data

and input the data into numerical models, which generate forecasts.

I receive these forecasts at the Weather Channel in Atlanta, Georgi

along with the forecasts made by The National Hurricane Center in Miami, Florida

My final forecast is a blend of the hurricane’s present track

and intensity my forecast, computer forecasts,

and the forecast from the National Hurricane Center.

Finally, I go on television and make a prediction about the path of the hurricane

and how it might affect people, on the coast and inland.

Thanks, Dr. Lyon.

Hey, how would you like to use computer simulations to study the behavior of hurricanes and then predict their paths, just like Dr. Lyons?

Shelley Canright has the scoop.

Welcome to my little piece of the world here at NASA headquarters in Washington DC.

From this location and with the help of some technology I am able to network across the country to NASA field centers and to other organizations that are interested in using NASA research data for use in classrooms, like yours.

Norbert has lined up some students in Monument Valley, Utah, who will share with you two dynamic websites on hurricanes.

Websites that use visualization,

remote sensing,

and simulation tools to immerse you in past and recent hurricane events and then present you with a challenge.

That will help you to think and act like a meteorologist, as you explore the website Earthpulse Center created by Riverdeep Interactive Center, and Exploring the Environment, developed by the NASA Classroom of the Future.

There are a lot of great activities here such as performing arts, National Honor Society, student council, and basketball.

This is a great place to go to school.

From the NASA CONNECT website, go to Norbert's lab.

Then click on the Activity button that will take you to the Earthpulse Center.

Go to the control room and select hurricanes.

Here you'll find 3 activity areas.

Forecasting,

analysis,

and hazard mitigation.

Click on the forecasting desk first.

The hurricane data archive provides access

from the past 50 years.

Search for a hurricane by either name or year

and then run a simulation of the storm.

As it moves across the Atlantic Basin compare and contrast tracks from different years to identify common patterns of behavior among the Atlantic Basin Hurricanes.

Draw your own prediction of a current storm's future movement

and behavior.

Come back a few days later to compare your forecast against the hurricane's actual path.

If there is not currently an active storm you can use a past hurricane to practice your forecasting skills.

At the analysis desk, you will compare the line graphs of several storms' wind history to identify common patterns of behavior.

You can also examine the inverse relationship between wind speed

and pressure in a hurricane using processed satellite imagery from The National Hurricane Center.

You'll be able to track data to tell a more complete story of a hurricane's life.

At the hazard mitigation desk, you'll be able to look at news stories that were published during some past storms to get an idea of the warnings that were issued as the hurricanes developed.

Take a virtual field trip down to hurricane territory from the safety of your own computer screen with the field cam.

By positioning the field cam on a map somewhere along the path of an impending hurricane, you might get a glimpse into the eye of the storm.

Issuing warnings to hurricane-prone areas is a risky task.

At the warning simulator, you get to set the guidelines for when to sound warning sirens for a particular coastal community.

Our second featured website is called Exploring the Environment.

This website provides the tools you'll need to complete the task of reviewing the action of the 1992 Hurricane Andrew, and of preparation for tracking, analyzing, and predicting the course of a new hurricane that may threaten North America in the future.

Using remote sensing images from NOAH weather satellites you will plot the hurricane's progress on a chart and make predictions about its landfall.

Thanks for watching NASA CONNECT.

Bye.

Bringing to you the power of digital learning, I'm Shelley Canright, for NASA CONNECT online.

This web activity is great.

I feel just like a meteorologist.

Speaking of meteorologists, Dr. Lyons told us earlier that to predict hurricanes, he needs data collected from the Hurricane Hunters.

Let’s head back to Kessler Air Force Base in Biloxi, Mississippi and meet one of the meteorologists in the Hurricane Hunters.

Describe the instruments the Hurricane Hunters use to collect data on a hurricane.

What symbol is used to describe the flight pattern?

Which of the 4 variables shown in the graph is constantly increasing?

The Hurricane Hunters are a group of men and women in the United States Air Force Reserve,

who fly these airplanes into the hurricanes to measure the storms.

The data we collect are given to The National Hurricane Center in Miami, Florida, who need to know exactly where the hurricane is,

how strong it is,

and what the winds are like.

But why do you have to fly into the storm?

Aren’t the satellite images enough?

The National Hurricane Center can get very good estimates of hurricanes from satellites, but sometimes hurricanes don’t follow the books.

Sometimes it may be difficult to find the eye or the center on the satellite pictures

or they may be stronger or weaker then they appear on the satellite.

That’s where we come in.

The more meteorologists know of what the hurricane is doing right now, the better they’ll be able to forecast what it will do in the future.

The measurements collected by the Hurricane Hunters makes forecasts about twenty-five percent more accurate, than just using satellite estimates alone.

This makes a huge difference, especially when you are trying to evacuate people on the coasts and save lives.

Okay, Val, so how do you measure a hurricane?

Well, Jennifer we have weather sensors mounted around the nose of our WC-130 aircraft and two weather stations inside.

Let me show you.

Great.

We collect data along different altitudes along our flight path.

In addition to these weather sensors, we also drop another weather instrument with a parachute that collects data from other altitudes as it falls through the atmosphere.

All of these instruments continuously measure temperature, moisture, air pressure, and wind.

The data we collect are immediately sent to The National Hurricane Center.

But how do you know where to fly into a hurricane?

Good question.

The National Hurricane Center calls us and gives us the hurricane’s forecasted latitude and longitude.

The navigator plots the hurricane’s position on a chart.

Then charts our flight path from Biloxi into the storm.

The navigator and pilot then discuss the pattern to fly into the storm.

You see, to make accurate measurements we fly a pattern that looks like an ‘x’.

We start in one corner of the hurricane, then fly to the center of the ‘x’ which is the eye or the center of the hurricane.

Then we fly out at least 105 miles on each leg of the ‘x’.

Each time coming back to the eye.

As we fly this pattern we collect data on temperature, moisture, air pressure, and wind and see how they change.

Two of the most important elements we measure are air pressure and wind.

Let’s look at this graph of air pressure and wind that we collected in a hurricane that we flew.

Ok, let me see if I can interpret it.

The horizontal axis begins at the center of the eye of the hurricane.

Then we have the eye wall here, and way out here we have the outer edge.

The vertical axis indicates an increase in intensity.

Right. What do you notice about the air pressure and wind in the eye of the hurricane?

Hmm…let's see.

The intensity of the air pressure and the wind is low at the center of the eye of the hurricane

but it begins to increase as you get close to the eye wall.

That's right.

And the lower the air pressure, the stronger the hurricane.

That's important information to know.

Let's look at the air pressure and wind at the eye wall.

What do you notice?

Wow. The wind really increased in intensity at the eyewall and the air pressure did too.

Right, and the air pressure continues to increase as you get to the outer edges of the hurricane, but notice the wind is at its strongest at the eye.

But this is just a graph of the air pressure and the wind.

You said you also collect data on temperature and moisture.

What would happen if we added that data to this graph?

Well, let's take a look.

Check it out.

The intensity of the temperature is really high in the eye of the hurricane and moisture is at its lowest.

This sure is a lot of information, Valerie.

It is but you know what?

A long time ago weather geeks did not have this volume of information.

They would simply look at a hurricane, use their memory and say, "Hmm, this reminds me of Hurricane Baker 26 years ago."

They would then base their forecasts for the current hurricane on what Hurricane Baker did way back then.

Today, the National Hurricane Center uses the data we collect from our flights to feed their computer-generated models or simulations of hurricanes.

These computer-generated models forecast how conditions change in a hurricane over time.

Knowing what the storm is doing right now helps the National Hurricane Center to predict the future path and the intensity of the storm.

From this information, hurricane watches and warnings are sent out to people along the coast.

When people are evacuated to safer areas because of an impending hurricane, then the mission of the Hurricane Hunters contributes to saving lives.

My thanks to all the Hurricane Hunters.