INFORMATION TO USERS

While the most advanced technology has been used to photograph and reproduce this manuscript, the quality of the reproduction is heavily dependent upon the quality of the material submitted. For example:

- Manuscript pages may have indistinct print. In such cases, the best available copy has been filmed.
- Manuscripts may not always be complete. In such cases, a note will indicate that it is not possible to obtain missing pages.
- Copyrighted material may have been removed from the manuscript. In such cases, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, and charts) are photographed by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps. Each oversize page is also filmed as one exposure and is available, for an additional charge, as a standard 35mm slide or as a 17”x 23” black and white photographic print.

Most photographs reproduce acceptably on positive microfilm or microfiche but lack the clarity on xerographic copies made from the microfilm. For an additional charge, 35mm slides of 6”x 9” black and white photographic prints are available for any photographs or illustrations that cannot be reproduced satisfactorily by xerography.
The effects of verbal and pictorial instructional formats on the comprehension of science concepts by hearing impaired subjects

Diebold, Thomas Joseph, Ph.D.

The Ohio State University, 1987

Copyright ©1987 by Diebold, Thomas Joseph. All rights reserved.
PLEASE NOTE:

In all cases this material has been filmed in the best possible way from the available copy. Problems encountered with this document have been identified here with a check mark ✓.

1. Glossy photographs or pages _____
2. Colored illustrations, paper or print ______
3. Photographs with dark background _____
4. Illustrations are poor copy ✓
5. Pages with black marks, not original copy ✓
6. Print shows through as there is text on both sides of page ______
7. Indistinct, broken or small print on several pages ✓
8. Print exceeds margin requirements ______
9. Tightly bound copy with print lost in spine ______
10. Computer printout pages with indistinct print ______
11. Page(s) ______ lacking when material received, and not available from school or author.
12. Page(s) ______ seem to be missing in numbering only as text follows.
13. Two pages numbered ______. Text follows.
14. Curling and wrinkled pages ______
15. Dissertation contains pages with print at a slant, filmed as received ______
16. Other______________________________

__________________________________________________________________________

__________________________________________________________________________

University Microfilms International
THE EFFECTS OF VERBAL AND PICTORIAL INSTRUCTIONAL FORMATS
ON THE COMPREHENSION OF SCIENCE CONCEPTS
BY HEARING IMPAIRED SUBJECTS

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

By

Thomas Joseph Diebold, B.S., M.A.

*****

The Ohio State University
1987

Dissertation Committee:
D.C. Cavin
J.L. Collins
R.H. Swassing
M.B. Waldron

Approved by

Raymond H. Swassing
Advisor
College of Education
Copyright by
Thomas Joseph Diebold
1987
To my wife
ACKNOWLEDGEMENTS

I express appreciation to Dr. Raymond S. Swassing for his timely suggestions and guidance throughout the research. Special thanks go to Dr. Manjula B. Waldron for her technical expertise, insight and guidance. Thanks are also due to Drs. Donald C. Cavin and James L. Collins for their support and helpful comments, and to Dr. Susan Rose for her resource materials and encouragement. Gratitude is also expressed to Jack Brownley and staff from the Columbus Hearing Impaired Program, Janet Gordon and staff from the Ohio School for the Deaf, and Elaine Horn and the staff from the Zanesville City Schools hearing impaired program. To my wife Janet, I offer loving thanks for her unshakable support and believing action throughout the trying times of this project. I also wish to thank all of the believers from my Bible fellowship for their prayers and support. Finally, I express my appreciation to Jim and Julie LeSar for access to their computer.
VITA

August 1, 1956 . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Born - Newark, Ohio

1978 . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . B.S., The Ohio State University, Newark, Ohio

1979 . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . M.A., The Ohio State University, Columbus, Ohio

1979-1982. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Teacher, hearing impaired program, Zanesville City Schools, Zanesville, Ohio

1983-1986. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Graduate Research Assistant Nisonger Center, The Ohio State University, Columbus, Ohio

1986-Present . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Low-Incidence Handicapped Supervisor, Southeastern Ohio Special Education Regional Resource Center, Athens, Ohio

PUBLICATIONS


FIELDS OF STUDY

Major Fields: Special Education
School Administration
Dr. Raymond H. Swassing
# TABLE OF CONTENTS

DEDICATION .................................................. ii  
ACKNOWLEDGEMENTS ....................................... iii  
VITA .................................................................. iv  
LIST OF TABLES ................................................ vii  
LIST OF FIGURES ............................................. viii  

<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. INTRODUCTION.</td>
<td>1</td>
</tr>
<tr>
<td>Introduction.</td>
<td>1</td>
</tr>
<tr>
<td>Problem Statement</td>
<td>5</td>
</tr>
<tr>
<td>Background.</td>
<td>7</td>
</tr>
<tr>
<td>Purpose.</td>
<td>13</td>
</tr>
<tr>
<td>Significance.</td>
<td>13</td>
</tr>
<tr>
<td>2. LITERATURE REVIEW</td>
<td>15</td>
</tr>
<tr>
<td>Cognitive Psychology.</td>
<td>15</td>
</tr>
<tr>
<td>The Deaf Learner.</td>
<td>19</td>
</tr>
<tr>
<td>Intelligence.</td>
<td>19</td>
</tr>
<tr>
<td>Cognition and Language.</td>
<td>21</td>
</tr>
<tr>
<td>Cognitive Processing.</td>
<td>25</td>
</tr>
<tr>
<td>Language Development and Reading.</td>
<td>35</td>
</tr>
<tr>
<td>Pictorial Input.</td>
<td>53</td>
</tr>
<tr>
<td>Combining Verbal and Pictorial.</td>
<td>59</td>
</tr>
<tr>
<td>Previous Studies.</td>
<td>65</td>
</tr>
<tr>
<td>Designing Instructional Formats</td>
<td>76</td>
</tr>
<tr>
<td>3. METHODOLOGY</td>
<td>79</td>
</tr>
<tr>
<td>Subjects.</td>
<td>79</td>
</tr>
<tr>
<td>Materials.</td>
<td>82</td>
</tr>
<tr>
<td>Procedure.</td>
<td>92</td>
</tr>
<tr>
<td>Hypotheses.</td>
<td>96</td>
</tr>
</tbody>
</table>
LIST OF FIGURES

FIGURES

<table>
<thead>
<tr>
<th>FIGURE</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Wileman's Continuum of Visual Symbols</td>
</tr>
<tr>
<td>2.</td>
<td>Example of Type I Visual: The Reader Slide</td>
</tr>
<tr>
<td>3.</td>
<td>Example of Type II Visual: Emphasized Reader Slide</td>
</tr>
<tr>
<td>4.</td>
<td>Example of Type III Visual: Reader Slide with Visual Cues to Meaning</td>
</tr>
<tr>
<td>5.</td>
<td>Example of Type IV Visual: Verbal/Visual Balance Slide</td>
</tr>
<tr>
<td>6.</td>
<td>Example of a Type V Visual: Pictorial or Graphic Symbol Slide with Verbal Cues to Meaning</td>
</tr>
<tr>
<td>7.</td>
<td>Example of Type VI Visual: Emphasized Pictorial or Graphic Slide</td>
</tr>
<tr>
<td>8.</td>
<td>Example of Type VII Visual: Pictorial or Graphic Symbol Slide</td>
</tr>
<tr>
<td>9.</td>
<td>Example of &quot;Over-Under&quot; Composition for Reduced Text/Diagram Format</td>
</tr>
<tr>
<td>10.</td>
<td>Example of &quot;Side-by-Side&quot; Composition for Reduced Text/Diagram Format</td>
</tr>
</tbody>
</table>
# LIST OF TABLES

<table>
<thead>
<tr>
<th>TABLES</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mean age and reading level of subjects by sex</td>
<td>80</td>
</tr>
<tr>
<td>2. Mean age and reading level of subjects by format groups</td>
<td>81</td>
</tr>
<tr>
<td>3. Mean Length Utterance of verbal components</td>
<td>85</td>
</tr>
<tr>
<td>4. Type-token Ratio of verbal components</td>
<td>86</td>
</tr>
<tr>
<td>5. Frequency and percentage of transformations in verbal components</td>
<td>88</td>
</tr>
<tr>
<td>6. Frequency and percentage of sentences with multiple transformations</td>
<td>89</td>
</tr>
<tr>
<td>7. Frequency of transformational types within verbal components</td>
<td>91</td>
</tr>
<tr>
<td>8. Verbal and pictorial content of formats</td>
<td>93</td>
</tr>
<tr>
<td>9. Analysis of covariance: Main effect of format</td>
<td>100</td>
</tr>
<tr>
<td>10. Analysis of covariance: Individual format effects</td>
<td>101</td>
</tr>
<tr>
<td>11. Analysis of covariance: Between group differences</td>
<td>103</td>
</tr>
<tr>
<td>12. Mean gain scores for male and female subjects</td>
<td>105</td>
</tr>
<tr>
<td>13. Analysis of covariance: Between group differences for male subjects</td>
<td>107</td>
</tr>
<tr>
<td>15. Rank order of format mean gain scores (overall)</td>
<td>109</td>
</tr>
<tr>
<td>16. Rank order of format mean gain scores by sex</td>
<td>110</td>
</tr>
<tr>
<td>TABLE</td>
<td>PAGE</td>
</tr>
<tr>
<td>-------</td>
<td>------</td>
</tr>
<tr>
<td>17. Analysis of covariance: Main effect of Mean Length Utterance</td>
<td>112</td>
</tr>
<tr>
<td>18. Analysis of covariance: Main effect of Type-Token Ratio</td>
<td>113</td>
</tr>
<tr>
<td>19. Analysis of covariance: Main effect of total number of words</td>
<td>115</td>
</tr>
<tr>
<td>20. Analysis of covariance: Main effect of total percentage of sentences with transformations</td>
<td>116</td>
</tr>
<tr>
<td>21. Analysis of covariance: Main effect of total number of pictures</td>
<td>117</td>
</tr>
</tbody>
</table>
Introduction

The eminent physicist, Albert Einstein indicated that the thought processes he utilized for many of his innovative theories were often completely non-verbal, mediated through visualized images. In a letter to his good friend Max Wertheimer, Einstein wrote: "Thoughts did not come in any verbal formulation. I rarely think in words at all. A thought comes, and I may try to express it in words afterwards." (Wertheimer, 1945, p. 184). In contrast to his obvious strengths in visual thinking, Einstein struggled with a marked disability in verbal thinking and the use of language (Patten, 1973). Due to language deficits Einstein was considered to be an academic failure in school.

A biographical review shows that Einstein had a disability in verbal realms that contrasts sharply with his ability in non-verbal spheres of activity. The scientist's poor school work, childhood misbehavior, and deficient and delayed language skills are explained by a developmental deficit in verbal learning probably due to a dysfunction of the dominant hemisphere. In the same way his extraordinary visual and spatial abilities can be explained by a compensatory increase in function of the non-dominant hemisphere. At
least one scientific genius was able to overcome a handicap by circumventing the verbal modality in which he was deficient and achieve greatness through the use of an unusual way of visual thinking. The suggestion is that other people might benefit from a similarly applied strategy for problem solving, and that our present verbally oriented educational system may be preventing geniuses in visual thinking from achieving their full potential (Patten, 1973, p. 415).

The evidence suggests that Einstein "had some kind of dominant hemisphere dysfunction since it is widely recognized that the dominant hemisphere is specialized for speech and verbal reasoning" (Patten, 1973, p. 418). Within the verbally-oriented environment of his first school in Munich, Einstein was regarded as a dull, slow learner. Later, he attended a special school at Aarau, which was founded by Pestalozzi, the famous Swiss educational reformer. The school at Aarau applied the educational approaches advocated by Pestalozzi, specifically the emphasis placed upon visual rather than verbal understanding as the basis of conceptual thinking and all knowledge (Patten, 1973). Einstein performed well at this school.

At last Einstein flourished in a situation which did not impair the free expression of the particular styles of thinking that were so congenial to him. With the recent organization and partial publication of the Einstein papers,
the evidence that this style of thinking was nonverbal and visually mediated cannot be doubted. (Patten, 1973, p. 417). Even today, most western educational systems stress the importance of verbally mediated modes of instruction, while de-emphasizing visually mediated learning. This emphasis can be detrimental to learners who are not proficient with the language or with verbal learning strategies.

Many researchers have noted that hearing impaired individuals are often linguistically "delayed" when compared to the normal hearing population (Furth, 1966, 1971; Meadow, 1980; Myklebust, 1964; Quigley & Paul, 1984). As a result, hearing impaired learners experience delays in academic achievement and the learning of ordinary academic subjects (Moores, 1978). Davis (1974) found that even a mild hearing loss can result in significant delays in the understanding of concepts. Deficits in academic achievement also become progressively more severe as deaf students advance to the higher grades (Blair, Peterson & Viehweg, 1985).

Is it possible that deaf students experience similar difficulties as did Albert Einstein? In his book Thinking Without Words, Hans Furth suggested that

Many deaf children prove failures, or near failures in academic subjects. The time required for them to cover the usual primary and secondary education is much longer as a rule than for the average child. Observing these children who have so much difficulty with ordinary school
subjects, one could not imagine them ever growing up to live normal adult lives. Yet they do just that! Could this startling change be attributed to the fact that the whole scholastic curriculum is based upon verbal skill while real life does not depend so exclusively upon it? These questions and related ones about the place of language in mature thinking lead the psychological researcher to consider whether the all-important stress placed upon verbal learning by teachers of the deaf is altogether advantageous (Furth, 1966, p. 13).

Recent studies of how the deaf subjects process information have suggested that the lack of auditory input may result in the development of a visual encoding system that differs from auditorially-based verbal encoding systems of normal hearing individuals (Goldin-Meadow & Mylander, 1979; Kretschmer & Kretschmer, 1978). Manning, Goble, Markham & LaBrech (1977) presented signs and words bilaterally and found that deaf subjects had weaker left hemisphere superiority for words than hearing subjects. Their findings suggest that deaf persons process information in a manner that differs from the normal hearing population. Educational methods which emphasize verbal approaches to learning may have a detrimental effect upon the academic performance of deaf learners similar to the situation which faced young Einstein.
Problem Statement

The measured academic achievement of hearing impaired students tends to fall short of the expected levels of performance as indicated on tests of cognitive development (Meadow, 1980). Deaf students typically have difficulty with language-related subjects. "Academic achievement is lowest in areas that rely on knowledge of English. Deaf students have difficulty with subjects such as reading and science, and they experience most success with subjects such as spelling and arithmetic computation." (Moores, 1978).

The attempts to improve the quality of education for deaf individuals have generally focused on teaching or remediating language (Standard English) as a prerequisite to academic achievement. This is a logical process since most educational materials require reading skills, and textbooks comprise the majority of instructional materials available to the educator. Yet, overall competence with the language is rarely attained and academic achievement for deaf learners continues to lag behind hearing norms. The average reading test performance for 18 year-old deaf students is approximately the same as the performance by fourth-grade hearing students (Moores, 1978). "The fact is that under our present educational system the vast majority of persons, born deaf, do not acquire functional language competence, even after undergoing many years of intensive training." (Furth, 1966, p. 13). Furth highlighted the continued overemphasis placed upon verbally-oriented instructional approaches that dominate deaf education. Few instructional approaches deviate
from this tradition. "Aside from special methods for teaching speech and English, little attention has been devoted to the development of curricula specifically designed for deaf children." (Moores, 1978, p. 258).

The problem of poor academic achievement reflects the inability of the educational system to develop alternatives which can circumvent the language barriers and adjust to the cognitive style of the deaf learner. The problem of academic achievement may lie more with the assumptions inherent to our educational approaches than with the language deficiencies of the deaf learner. Quigley and Kretschmer (1982) noted that

Most researchers and most educators of deaf children presently accept that any differences that do exist in intellectual and cognitive functioning between deaf and hearing persons are not significant for adequate functioning in society, and that educational, occupational, and other deficiencies in deaf people are the result of our present inability to fully help deaf people and use their abilities rather than the result of any inherent deficiencies in those abilities. (p. 63).

The deaf learner will continue to experience delays in academic achievement when compared to normally hearing students as long as standard "English" is considered pre-requisite to learning. Educational programs which rely on and emphasize verbal learning strategies will only continue to teach towards an area of weakness for deaf learners (Standard English), rather than adjust to learning style.
Background

Studies and national statistics indicate that the linguistic skills and academic achievement of hearing impaired learners are delayed when compared to that of hearing students. The linguistic skills of hearing impaired subjects have traditionally been evaluated in terms of (a) written production and (b) reading ability, both measures of proficiency in Standard English.

In an early study of the written production by deaf subjects, Heider and Heider (1940) compared the compositions of deaf subjects (ages 11-17) with the compositions of hearing subjects (ages 8-14). Subjects were directed to describe a motion picture that they viewed. The deaf subjects tended to write more rigid and simple sentences when compared to the compositions of hearing subjects. The authors concluded that deaf individuals produced patterns that were qualitatively different and suggested that hearing impaired persons had thought processes that were dissimilar from normal hearing individuals.

In a study examining the sentence construction of deaf subjects ages six to twelve, Walter (1955) noted that the patterns produced lacked the flexibility and complexity of sentences produced by hearing subjects. Myklebust (1966) compared the written syntax scores of deaf and hearing subjects (ages 7-15), and noted that the mean score for 15 year-old deaf subjects was comparable to the mean score for 7 year-old hearing subjects. Moores (1978) cited the work of Simmons (1962) regarding the diversity of vocabulary produced by deaf
subjects according to a type-token ratio, and found that deaf subjects produced more stereotyped, rigid, and redundant structures and vocabulary usage. Quigley and Paul (1984) stated in their book, *Language and Deafness*, that an Examination of language samples from Thompson (1936) to Quigley, Wilbur, Power, Montanelli, and Steinkamp (1976), and examination of the quantitative data reported in those studies indicated that there has been no general improvement in written language either, in spite of much greater knowledge and understanding now available on the matter. (p. 162).

The reading comprehension of deaf subjects has also been studied extensively. Pintner and Patterson (1916) found that deaf subjects (ages 14-16) had median reading scores that were comparable to the scores for 7 year-old hearing subjects on a test that evaluated the ability to follow written directions. Pugh (1946) and Myklebust (1960) also noted lower reading scores for deaf subjects.

Furth (1966) analyzed a study by Wrightstone, Aronow and Moskowitz (1963) that examined reading scores by deaf subjects on the Metropolitan Achievement Test. Furth (1966) noted that only 8% of the deaf students (ages 10½ to 16½) in this national sampling scored at or above the fourth grade reading level. Furth (1966) also noted that the average rate of growth measured in terms of
grade equivalent scores increased at less than one grade level for
every five years of instruction.

Trybus and Karchmer (1977) found that the median grade equivalent
for 20 year-old deaf individuals was 4.5 on the SAT. They also
found that only 10% of the best reading group (age 18) scored
at or above the eighth grade level.

As a result of delays in both written production and reading
comprehension, deaf individuals experience significant delays in
academic achievement. Moores (1978) analyzed the scores obtained by
deaf students on the various subtests of the SAT, and observed specific
patterns of delayed performance. Achievement was highest in areas
which require "mechanical" skills (spelling and arithmetic
computation). Achievement was lowest for areas requiring proficiency
in Standard English (word meaning, paragraph meaning, social studies,
science and word study skills). To illustrate this pattern, Moores
(1978) pointed out that arithmetic computation scores were higher
than scores on arithmetic applications or concepts, subtests which
emphasize reading.

Overall, the scores for the deaf students were consistently
lower than the scores obtained by their hearing peers. The average
17 year-old deaf student (grade 11 or 12) scored at the 6.03 grade
level for arithmetic achievement and 4.02 grade level for paragraph
meaning.

Both scores are a shameful indictment of our educational
programs. By definition, a 17 year-old student should
achieve at the twelfth-grade level. Thus deaf students at age 17 achieve six years below their potential on a standardized test of Arithmetic Computation, one of their highest areas of achievement, and eight years below on a test of Paragraph Meaning. (Moores, 1978, p. 256).

Language deficiencies are closely associated with delays in academic achievement for deaf students. This negative relationship is further compounded by an over-emphasis on verbal modes of learning, both in regular education and in deaf education. This over-emphasis can be attributed in part to how we have viewed the relationship between thinking and perception in theories of learning and cognition.

The mental functions of visual perception and thinking have historically been separated in principle by psychological and physiological theory, and as a result, modern education is mostly devoted to verbal and numeric "thinking" skills. We have elevated the importance of reading, writing and arithmetic (skills which are detached from sensory perception) above art, music and physical education because of our concern in western education with words and numbers (Arnheim, 1965). This tradition is based upon the assumption that man thinks in words alone, and that without words, no thinking can occur. Only in kindergarten and first grade is there a cooperation of all the essential powers of the human mind by equal emphasis upon sensory perception experiences and verbal-numeric skills. However, this natural and sensible procedure is dismissed
in later grades as an obstacle to training in the proper abstraction of verbal-numeric reasoning (Arnheim, 1965).

In contrast to the traditional verbal-dominant view of thinking, Feldman (1976) stated that written words are actually representations of visual images and that "we deliberately unlearn or repress our visual grammar in the course of becoming proficient readers of writing" (p. 196). Hortin (1982) argued that although we are basically a visual society, schools emphasize verbal approaches to learning. The whole educational process in western society rests primarily on the development and use of the verbal skills of speaking, reading and writing (Elwell & Hess, 1979). "Many of the calls for more visual learning in the schools are based on the idea that school learning is primarily verbal while most children just entering school have been operating in a predominately visual environment." (Hortin, 1981, p. 197).

Deaf education also emphasizes verbal learning approaches. Behrens and Meisegeier (1968) reviewed the professional literature on deaf education and noted that the most common topics found in professional journals were general issues, language, speech, and lipreading. Moores (1978) suggested that because speech and language are viewed as the most important content areas for deaf education, the areas of math, science and social studies have received insufficient attention.

Although the education of the deaf is viewed by much of the lay public and, unfortunately, by many of its
practitioners as an esoteric, somewhat mystical process, very little has been done in the way of development of special curricula outside of language and speech teaching and auditory training. (Moores, 1978, p. 257).

In the foreword to Scouten's book, *Turning Points in the Education of Deaf People*, Davilia (1984) wrote:

Throughout the centuries, the men and women who have pioneered developments in the field of education of the deaf have been obsessed with singleness of purpose: teaching deaf children to process spoken and written language accurately, thereby permitting them to master learning and to interact successfully with the world around them...the same basic objectives have guided, and more or less eluded educators of the deaf over the years (p. viii).

In essence, both regular education and deaf education emphasize verbal approaches to learning. The basic difference between deaf education and regular education are the special methods for developing communication and language skills in deaf learners. These skills are regarded as prerequisites to learning Standard English, which in turn is regarded as the prerequisite for learning in our schools. Although these special methods do help, the deaf learner continues to experience significant deficits in the mastery of English and ultimately with overall academic achievement.
Purpose

The purpose of this study is to investigate the feasibility of circumventing or supplementing instructional methods which over-emphasize verbal-based learning approaches for use with hearing impaired learners. Specifically, this study examines the effects of varying degrees of verbal complexity and pictorial content contained in printed instructional formats on the comprehension of science content by hearing impaired students.

Significance

Studies concerned with improving the academic achievement of deaf students focus on the modification, adjustment or development of instructional methods or materials which meet the needs of the hearing impaired learner. Since deaf learners demonstrate "delays" in the mastery of Standard English, most studies have emphasized the acquisition of linguistic skills such as speech, auditory training, English language training or reading. Some theorists have suggested teaching English as a second language (Quigley & Paul, 1984). All of these approaches emphasize verbal-based learning, and are characterized by the linear, sequential processing of verbal information. Research has indicated that deaf individuals have greater difficulty with linear, sequential presentations of information than do normal hearing individuals.

Relatively few studies have investigated alternative instructional methods which place equal emphasis upon non-verbal learning strategies, while striving to simplify the complexities of verbal information.
presented in Standard English. Information presented in pictorial formats tends to be more spatially oriented and appeals to the non-dominant, or right hemisphere for processing. Research has indicated that the deaf may be more proficient with spatially-oriented information than with sequentially-oriented information. Secondly, printed diagrams permit re-exposure to the information unlike the passing nature of sign or spoken modes. Re-exposure is a critical factor for learning with the hearing impaired learner (Waldron, Diebold & Rose, 1985). Pictorial approaches to instruction capitalize on both of these aspects, and suggest a possible means for improving academic achievement by replacing or supplementing verbal-emphasized approaches. Pictorially-based instructional strategies may also be applicable to other populations which experience linguistic delays.
CHAPTER 2
LITERATURE REVIEW

This study addresses a topic which includes many related areas of research and theory that deal with the deaf learner. The areas covered in the Literature Review are arranged as follows:

1. Cognitive Psychology
2. The Deaf Learner
   a. Intelligence
   b. Cognition and Language
   c. Cognitive Processing
   d. Language Development and Reading
3. Information Input
   a. Verbal
   b. Pictorial
   c. Combining Verbal and Pictorial
4. Previous Studies
5. Designing Instructional Formats

Cognitive Psychology

An enduring question that has historically intrigued and divided psychologists and philosophers has centered on how the external world is represented in the human mind. Two schools of thought have evolved
regarding this issue, one emphasizing mental structures and the other emphasizing mental processes.

Rene Descartes theorized that man possessed innate structures which determined intellectual and perceptual functioning, as well as religious and moral orientation. John Locke favored the process orientation by describing the human mind as initially a "tabla rasa," or blank slate, from which all structures developed as a function of learning experiences.

Structuralism regarded mental structures as the most important aspect of a person's mind. The goal of structuralism was to describe the relationships among the contents of awareness through introspection and subsequent verbal reports (Reynolds & Flagg, 1983). Unfortunately, such a process is difficult. How does one think about and describe the process of thinking? Introspection alone is insufficient to define a mental concept (Reynolds & Flagg, 1983).

John Watson developed the "science of behavior," or behaviorism, in response to the ambiguity of structuralism. Watson's work focused on those environmental influences which affect behavior, and introduced the concept of empirical observation and measurement of behavior. Behavioral psychology promoted the concept of associative bonds between stimuli and responses (S-R) to account for influences external to the subject. The S-R paradigm was also applied to internal "thinking" in the form of associative bonds between memory elements. However, research efforts to describe many of the higher mental processes of man were avoided or insufficiently explained by the
stimulus, response and reinforcement paradigm (Reynolds & Flagg, 1983).

After World War II, behaviorists began to allow for the introduction of some non-observable characteristics of the organism as long as they could be operationalized or tied directly to observable behavior. Neo-behaviorism developed many concepts from animal learning and verbal learning studies. This approach described complex processes based upon studies of more simple behaviors. Complex behaviors were organized in a sequential or linear form because it was theorized that associative bonds were established in this manner.

Cognitive psychology retained many of the features of structuralism, behaviorism, and neo-behaviorism. Cognitive psychology retained mental structures and processes as valid targets of inquiry. Learning and memory were considered to be keys to describing cognitive processes. Cognitive psychology also emphasized the controlled experimental approach which had distinguished behavioral approaches.

Cognitive psychology also found additional roots in the disciplines of computer science, information theory and linguistics. Many of the terms used in cognitive psychology found their origins in these fields.

The cognitive approach regarded the learner as active rather than passive. The learner is viewed as an active organism which searches, filters, selectively acts upon, reorganizes and develops information. Reynolds and Flagg (1983) listed the following beliefs that make the
cognitive perspective appropriate for investigating how the deaf learn:

1. The importance of the selection of stimulus information. Most of the time more information impinges on us than our limited capacities can handle. (Reynolds & Flagg, 1983, p. 14).
   - Deaf individuals have limited auditory stimulus pathways for the reception and decoding of information/auditory stimulus. This condition implies not only quantitative but qualitative differences in stimulus reception and selection.

2. The importance of selecting appropriate processing strategies (largely under voluntary control) to meet the demands of the task. (Reynolds & Flagg, 1983, p. 14).
   - Auditory processing strategies are severely limited for the deaf learner. This condition implies a forced selection of non-auditory processing strategies for information (visual or auditory).

   - Research comparing the Alpha and Beta brain wave patterns over Wernicke's area for deaf and hearing subjects indicated differences suggesting a difference in brain organization. (Waldron, Farber, & Rose, 1984).
- Although the hemispheres tend to specialize for different cognitive processes, they are not independent systems. Some language processing may take place in the right hemisphere when the left hemisphere is damaged (language processing typically involves more left hemispheric processing).

5. The constantly active nature of cognitive processes. The system is always active and at work. (Reynolds & Flagg, 1983, p. 14).
- The cognitive psychology approach permits the researcher to analyze the learning process in terms of information input, acquisition and processing. This approach is essential for the design of materials and instruction which capitalize upon learning style and processing needs.

The Deaf Learner: Intelligence

Historically, the perspectives regarding the intellectual capabilities of deaf individuals have changed. Early studies regarded the deaf population as intellectually inferior when compared to the normal hearing population. Pintner and Reamer (1920) noted that deaf subjects exhibited specific deficits in various aspects of cognitive functioning when completing paper-and-pencil tasks. Pintner, Eisenson and Stanton (1941) concluded that hearing impaired individuals were intellectually inferior after reviewing performance
data on Draw-a-Man tests, performance tests, and various drawing tests. Pintner and his colleagues concluded that deaf students could be expected to have an average retardation of ten IQ points.

Myklebust (1960) reviewed the research completed in the years following Pintner's work, and noted that scores on standardized intelligence tests indicated that hearing impaired subjects were basically equal to hearing subjects on global measures, but that subtest scores tended to differ. He concluded that deaf subjects were quantitatively equal to the normal hearing population, but not necessarily qualitatively equal when verbal factors were controlled on the various tasks. Myklebust and Brutton (1953) felt that deafness tended to functionally restrict an individual to a world of concrete objects and things. Myklebust (1960) concluded that deaf persons were intellectually more concrete and less abstract than hearing individuals.

Rosenstein (1961) observed that no differences in conceptual performance existed between deaf and hearing subjects when linguistic factors involved in various tasks were within the language experience of the deaf subjects. Rosenstein (1961) concluded that deaf individuals were indeed capable of "abstract" thought.

Furth (1966) also contended that individuals with deafness were intellectually normal. He attributed the poorer performances to either a lack of general experience with the content of tasks or specific task conditions that subtly favored linguistic skills.
Quigley and Kretschmer (1982) mentioned three specific influences which were biased against deaf subjects: (1) the inability of the researcher to convey the directions for completing the task; (2) implicit verbal biases to the solution; or (3) general deficits in experience by deaf subjects.

Vernon (1967) reviewed the research on the intelligence of deaf subjects conducted between 1930 and 1966, and concluded that deaf subjects performed as well as hearing subjects on a wide variety of tasks. Moores (1978) summarized the currently accepted position regarding the intellectual capabilities of deaf individuals:

The available evidence suggests that the condition of deafness imposes no limitations on the intellectual capabilities of individuals. In addition, there is no evidence to suggest that deaf persons think in more "concrete" ways than the hearing or that their intellectual functioning is in any way less sophisticated. (p. 137).

The Deaf Learner: Cognition and Language

Although deaf persons are regarded as intellectually normal, differences between the deaf and hearing do exist relative to proficiency with Standard English. The relationship between cognition and language needs to be examined in order to describe how language affects (or is affected by) cognitive processing. Two perspectives of this relationship are evident in theory: the language-dominant approach and the cognitive-dominant approach.
Most language-dominant theories are related to the Whorfian Hypothesis which states that: (a) language selectively emphasizes certain environmental stimulus, (b) that the language of society shapes our thinking, and (c) that language constrains our mode of thinking. Watson postulated that thinking is simply silent speech (cited in Furth, 1966). Sapir (1958) declared that not only does language precede cognition, but that all thinking takes place in language. Staats and Staats (1963) developed a reductionist theory of this relationship. In their theory, thinking is reduced to language, language is reduced to a mediating response and mediating responses are reduced to a form of conditioning.

Although the arguments of the Whorfian Hypothesis appear to be valid in many respects, the position restricts thinking to verbal modes of mediation that reflect the spoken language. The language-dominant approach fails to address the issue of modes of mediation which do not reflect the spoken language (e.g., sign language) or non-verbal mediators (e.g., visualizations). Quigley and Paul (1984) noted that some researchers have modified the language-dominant approach and concluded that although language may not dictate thought, it does influence it.

The cognitive-dominant approach argues that linguistic competence is determined by cognitive development. Piaget stated that language is not enough to explain thought, because the structures that characterize thought have their roots in actions and sensorimotor
mechanisms that are deeper than language. Slobin (1973) contended that language merely maps what is known and is a natural extension of cognitive development. Language is a subset of cognition as are perception, attention, memory and problem solving.

Vygotsky offered an alternative perspective on the relationship between thought and language. He postulated that thought and speech have different roots in ontogenetic development. Normal speech development has a "pre-intellectual" stage and normal thought development has a "pre-linguistic" stage. Each of these systems develop relatively independently of each other up to a certain point, at which they become intertwined: speech becomes rational and thought becomes verbal (Vygotsky, 1962).

Cognitive processing can take place without verbal mediation. Despite the tenable arguments of the other theories, only the cognitive-dominant theory can account for non-verbally mediated thinking. "The present weight of evidence in favor of the cognitive-dominant hypothesis is accepted" (Quigley & Paul, 1984, p. 31).

James (1890) and Binet and Simon (1910) supported the cognitive-dominant theory by concluding that the thought processes of deaf persons developed before language skills. In fact, Furth (1966) regarded hearing impaired individuals as ideal subjects for examining the development of cognitive abilities free of the influence of language. Furth assumed that deaf persons were language-free in their cognitive processing because of their linguistic deficits in Standard English. He concluded that thinking does not need the
support of a symbolic system such as the "living language" of society, because deaf adults were able to function in society despite language deficits. Furth (1966) also concluded that intelligence is not dependent upon a language system, but rather that the comprehension and use of a ready-made language depends upon the structures of intelligence.

Moores (1978) disagreed with Furth's assumption that deaf individuals are "language-free." Moores noted that Furth's position was based upon reading scores, and merely reflected deficits in Standard English, not the lack of a verbal mediating system such as sign language.

American Sign Language has been demonstrated to be a bona fide language according to the criteria established by Bloom and Lahey (1978). Sign language has its own grammatical structure which differs from Standard English (Wilbur, 1979). Therefore, sign language can function as an internal symbolic system and is considered to be a language. Deaf persons are not language-free as assumed by Furth. However, Furth's conclusions highlight the incorrect assumptions of the language-dominant theorists which describe thinking as only "silent speech".

Hearing people are known to use their initial phonology based language as an internal mediator (internal speech) in various thinking tasks and to a certain extent in reading. It is important to develop language and reading in deaf children to know what internal codes they use.
(visual imagery, internal speech, signs, manual alphabet, etc.) as symbolic mediators. (Quigley & Paul, 1984, p. 32).

Language functions externally to communicate by way of a standardized set of rules and internally as an idiosyncratic symbol system to represent reality. Language does influence cognition, but it is important to recognize that cognition is not dependent on language.

Thinking is like communication in that it involves both a mode and a code. The mode is the type of symbolic mediator used and the code is the ordered arrangement of the symbols that establishes the relationship among them. Internalized speech may be organized according to the English or Spanish coding systems. Signs may be organized according to the English word order or American Sign Language.

The spatial arrangement of visual images also involves a structure or code that establishes the relationship among the symbolic mediators. Thought, like communication, may be mediated by a variety of modes and codes, and should not be perceived as a single mode (internalized speech) or single code (Standard English) process.

**The Deaf Learner: Cognitive Processing**

Many researchers have suggested that when one sensory modality is absent or significantly limited in receiving input from the environment, the interrelationship among the other modalities may be affected. Kelly (1978), Neville and Bellugi (1977), Myklebust (1964) and Waldron (1982) have suggested that this situation may
exist for hearing impaired persons. Waldron and Rose (1984) suggested that a cortical reorganization may be expected due to the different feedback/input pathways available to the deaf individual. Studies comparing hemispheric lateralization, learning style, reasoning ability, and memory suggest that deaf individuals process information in a different manner than their hearing peers.

Lateralization studies have provided a means of describing processing differences that may occur as a result of injury, disease or handicap. Various approaches to studying cerebral specialization have permitted researchers to describe how the brain functions and to map the highly elaborate apparatus of various brain structures (Luria, 1970; Neville & Bellugi, 1978).

For normal hearing subjects, the left hemisphere appears to process stimuli for speech and language functions while the right hemisphere processes non-linguistic and perceptual stimuli (Neville & Bellugi, 1978). Research conducted with normally hearing, commissurotomized patients has indicated the left hemisphere is dominant when processing language-related tasks and the right is dominant when processing visual-spatial tasks. The left hemisphere also appears to be more specialized for analytical processing, while the right hemisphere is more specialized for gestalt processing (Bogen, 1969; Nebes, 1974).

However, the hemispheres are not to be viewed as totally independent processing systems with completely separate functioning. Research has indicated that the right hemisphere can play a vital
role in the recovery of speech and language-related functioning in cases where the left hemisphere has been damaged or is malfunctioning (Searlman, 1977). The available data suggests that the hemispheres have specialized roles for processing information with some interaction between the two hemispheres.

Lenneberg (1976) examined adult deaf subjects with left-brain injury and concluded that deaf persons also tend to exhibit left-hemispheric dominance for language. However, Rodda, Buranyi, Cumming and Muendel-Atherstone (1985) cautioned that the subjects in Lenneberg's study were not representative of the deaf population in terms of age of onset, etiology, degree of loss or level of education. Kimura (1976) noted that for seven cases of deaf aphasia cited in the literature, an association existed between manual communication disorders and left-hemisphere control of complex motor (non-language) behavior. McKeever, Hoemann, Florian and VanDeuenter (1976) also noted that similar deaf patients may be demonstrating motor skill deficits rather than aphasia.

Studies of neurologically normal deaf subjects have been more consistent and indicate differences between deaf and hearing learners. Manning, Goble, Markman and LaBreche (1977) noted that hearing subjects tended to lateralize to the left hemisphere for processing words presented to the separate visual fields while deaf subjects did not demonstrate lateral asymmetries. In fact, the deaf subjects did not demonstrate lateral asymmetries when presented with sign language stimulus.
Wilson (1977) found no evidence of cerebral specialization for language in deaf subjects when presented letters and signs unilaterally to the visual fields. Poizner, Battison and Lane (1979) also noted no hemispheric dominance when deaf subjects were presented with a series of three slides with sign and printed words. It would appear that deaf subjects do not evidence the same pattern of hemispheric dominance as do hearing subjects.

Waldron, Farber and Rose (1984) collected EEG and task performance data from three groups of male subjects: profoundly deaf subjects who signed from an early age, profoundly deaf subjects who only used oral communication (speech and speechreading), and normal hearing subjects. Alpha and Beta brain wave patterns over the Wernicke's area were compared across groups by tasks. At baseline, subjects were to focus on a dot displayed on a computer screen with their eyes open while not engaging in any formal cognitive activity. Both hearing and deaf subjects who signed evidenced more left hemispheric activity while oral deaf subjects had very little activity in the left hemisphere. EEG data from Mooney faces tasks showed considerably more right hemisphere activity for oral deaf subjects than for either deaf signers or normal hearing subjects. Data from pattern recognition tasks indicated that there was more activity in the left hemisphere for both hearing and deaf signers, whereas the oral deaf subjects continued to show greater right hemispheric activity. Irrespective of the tasks, signers exhibited greater cortical activity than oral or hearing subjects.
The authors suggested that this may be due to the fact that visual information requires more memory storage and inherent resources.

These results were consistent with the findings of Neville (1978). Her work with visual evoked potentials indicated that normal and signing deaf subjects evidenced cerebral specialization while oral subjects did not. Phippard (1977) and Varga-Khadem (1982) found that orally-trained deaf subjects processed verbal information more advantageously in the right hemisphere than in the left, the reverse of the normal hearing model. Manually-trained deaf subjects did not display an hemispheric advantage.

All of these hemispheric studies suggest that the hearing impaired learner processes information in a different manner than his hearing counterpart. Phippard (1977) suggested that the type of communication system used (oral or manual) may influence lateralization patterns. Neville and Bellugi (1978) suggested that the acquisition of a formal language may be a critical variable in the development of hemispheric specialization. Waldron, Faber and Rose (1984) stated that the sensory mechanism used in acquiring and coding information probably leads to different cortical organizations. The differences in processing between deaf and hearing individuals may be attributed to different sensory feedback modalities. Thus, we can expect a substantial reorganization of the brain, both structurally and functionally, for the congenitally profoundly deaf individual (Waldron, Farber & Rose, 1984).
The nature of the input stimulus is very different. Speaking involves segments of sounds organized in a sequential manner while sign involves aspects of movement that occur almost simultaneously at the word level (Stokoe, 1978). Both the stimulus and the processing of the stimulus differ. Qualitatively, the deaf and hearing have different processing systems which are specialized as a result of adaption to particular aspects or qualities of the input stimulus.

Deaf individuals process verbal or iconic stimulus codes equally well in the right hemisphere (Kelly & Tomlinson-Keasey, 1978). When examining processing speed, Kelly and Tomlinson-Keasey (1977) noted that deaf subjects process words and pictures faster in the right hemisphere, including both concrete and abstract stimuli. They concluded that deaf individuals process all stimuli with a visual coding system.

Studies of learning style also provide indications of processing differences. Parasnis and Long (1979) evaluated processing and learning styles according to measures of field dependence and field independence. Deaf subjects had weak lateralization and were more field dependent in learning style than hearing subjects. Parasnis and Long (1979) attributed these differences to the lack of auditory input for deaf subjects which resulted in different processing strengths and learning experiences. Gibson (1985) also
noted a significant relationship between field dependence and verbal ability for hearing impaired subjects.

The cognitive style of the deaf learner has also been examined in view of Gestalt and analytical processing principles, which are associated with field dependence and field independence. Gestalt principles describe the tendency of the human mind to perceive objects as structural wholes rather than disperse elements, whereas analytical processing involves the separation of elements within a structural whole. Furth and Mendez (1963) compared deaf and hearing subjects on various visual tasks and concluded that deaf subjects were less analytical than hearing subjects in their processing style and consistently organized precepts according to Gestalt principles. Furth (1964) suggested that deaf adults in this study suffered some permanent conceptual deficiency in the use and comprehension of logical classes and combinations, both considered to be analytical skills. Furth (1966) concluded that deaf persons appear to use a less sophisticated approach toward organizing precepts and rely more on preverbal modes of perceptual organization.

Sharpe (1984) observed that deaf subjects performed more poorly than hearing subjects on tests of analogical reasoning with both word and figure stimulus, and concluded that the oral-aural mode of communication provides sensory experiences that facilitate complex cognition. Thus, Sharpe attributed the observed deficiency to experience rather than to a permanent conceptual deficiency as did Furth.
Furth (1966) presented evidence that the deaf subjects were approximately five years late in grasping logical principles as indicated by performance on Piagetian conservation tasks. Meadow (1980) suggested that deaf persons learn the concepts of opposition, analogy and superordinate reasoning in the same sequence as hearing individuals, but at a later time. Olsson and Furth (Furth, 1966) attributed similar delays to the lack of auditory stimulus, mediation and memory which are not available to deaf learners. They also noted that deaf subjects performed better with the simultaneous presentation of digits or forms than with successive presentations.

Deaf subjects perform more poorly than the hearing on tasks requiring sequential memory (Quigley & Paul, 1984) and show a cognitive style preference for spatial reasoning (Martin, 1985). Due to the limitations placed upon temporal sequential processing as a result of auditory input deficits, the deaf learner may rely on a visual-spatial perceptual coding system for processing language (Parasnis & Samar, 1982; Waldron & Rose, 1984). This visual coding system places the usual temporal-sequential coding system on a lower priority for processing information (Waldron & Rose, 1984).

The lack of auditory coding strategies results in deficient memory for deaf individuals (Koh, Vernon & Bailey, 1971; Pintner & Patterson, 1917). Although some orally trained individuals may evidence the use of some articulatory codes, most deaf individuals use a visual code such as fingerspelling to aid memory (Wallace, 1972). Bellugi, Klima and Siple (1975) compared
deaf and hearing subjects for recall memory of signs. Deaf subjects tended to make formational errors while the hearing subjects made mostly semantic errors, indicating that two different coding systems were in use. Deaf subjects coded according to visual memory of the sign while the hearing subjects transferred the visual code into an auditory memory code based on the semantic meaning of the word. Furth (1963) observed that hearing students used verbalized principles of classification more readily than deaf students.

Boshoven, McNeil and Harvey (1982) analyzed how deaf and hearing subjects process drawings for recall. They noticed that deaf subjects utilized non-verbal referents while the hearing subjects used verbal referents. Their conclusions concurred with Furth and Mendez (1963), that overall, deaf individuals apply Holistic/Gestalt processing strategies while hearing individuals tend to rely on analytical processing strategies involving verbal reasoning skills.

The availability of "permanent" stimuli for rehearsal is an important factor for the deaf learner. Wilson (1981) described the importance of note-taking for college level deaf students. Note-taking services permit the deaf learner re-exposure to the information presented during instruction and helps to counter the negative effects of temporal, disseminating information (signed or spoken) that is sequential in nature (Waldron & Diebold, 1984).
Davey and LaSasso (1984) noted that reading scores were significantly higher when hearing impaired subjects were allowed to review the printed information. The importance of this permanence aspect is also evident when considering that reading was found to be the optimal receptive medium for the deaf learner, surpassing manual and oral modes (White & Stevenson, 1975). In reading, the subject can control the speed of presentation as well as look back over difficult passages. These processes are not available for oral or signed modes which are typically externally paced and temporal or passing.

There is no clear evidence that the coding strategies of deaf individuals are inevitably inferior to those of hearing individuals. It is clear that these strategies differ. Memory and information processing can function without auditory involvement or Standard English modes of processing. Unfortunately for deaf students, hearing students are proficient with auditorially-based, temporal-sequential processing. As a result, our schools emphasize these modes of processing almost exclusively, while assuming that the deaf learner must master these modes in order to learn.

In summary, hemispheric studies indicate that the deaf learner processes information in a different manner than the normal hearing population. Differences between deaf and hearing subjects can be attributed to differences in sensory feedback modalities, (and not a simple developmental delay in language). The sensory mechanisms used in acquiring and coding information probably lead
to different cortical organizations. Due to the limited auditory stimulus reception pathway we may expect a substantial reorganization of the structural and functional aspects of the brain for the congenitally profoundly deaf individual (Waldron & Rose, 1984). As a result, the learning style of the deaf learner is more field dependent and tends to rely more on Holistic/Gestalt processing and less upon analytical processing. Deaf learners are more proficient with spatially present information than with sequentially oriented information. Information tends to be processed in a visual rather than an auditory code. Finally, the hearing impaired learner appears to process information that has re-exposure better than information that is temporary and passing.

The Deaf Learner: English Language Development and Reading

In 1957, Noam Chomsky's book *Syntactic Structures* presented a new framework for viewing language that overcame many of the inadequacies of the earlier structural syntax theories (Russell, Quigley & Power, 1976). Chomsky's "generative transformational grammar" model provided a simple means for comparing the English language competencies of deaf and hearing subjects. Chomsky's model provided the framework for the design of the experimental instructional formats in this study.

As with all language theories, Chomsky's model cannot completely describe all the different ways that languages work, for "all grammars leak" (Stokoe, 1980). However, Chomsky's work did provide
a more complete means for describing the processes of English language coding and decoding.

Rather than simply attempting to describe the structure of language as the structuralists had, Chomsky wanted to explain it, and for this reason proposed a "generative" model of syntax which employed "transformations" to link the underlying meaning of a sentence to the sentence as it was actually pronounced (or written; the general principles are the same). (pp. 14-15).

Chomsky (1957) made the fundamental distinction between competence (the person's knowledge of his language) and performance (the actual use of the language in real-life situations). "Therefore Chomsky's grammar was concerned with defining the 'internalized' set of rules of an 'ideal' native speaker (or hearer) or competence as opposed to the sometimes inconsistent language as it is outwardly used, referred to as performance." (Russell, Quigley & Power, 1976). Chomsky's approach permitted comparisons between the internalized set of rules operated by hearing and deaf individuals for processing English.

Chomsky proposed the mechanism of the transformational rule which is applied to the deep, or underlying structures to "derive" the surface structure. The deep structure expresses the underlying meaning of a sentence and is the level at which grammatical relationships are preserved or are very abstractly represented.
Deep structures are often formally represented by tree diagrams to portray relationships among components. The surface structure is the sentence as it is actually produced to which the phonological rules apply. It should be noted that this model, as well as most theoretical models of language, is based upon phonological (auditory) processing.

The deep structure results from the application of phrase structure rules and lexical rules. Phrase structure rules define membership in various grammatical classes of the language. For example, the phrase structure rule "S = NP + VP" indicates that a sentence (S) consists of a noun phrase (NP) plus a verb phrase (VP).

Sentence: The boy runs.

\[ S = NP + VP \]

The deep structure is subject to transformational rules which link the underlying meaning of a sentence to the sentence as it is actually produced. Chomsky developed the concept of the basic, kernel sentence, such as the following example:

Sentence: The dog bit John

\[ S = NP + Vt + NP \]

This sentence may also be expressed with the optional transformation, passivization, which involves both the movement and addition of words.

Sentence: John was bitten by the dog.

\[ S = NP + Vt + NP \]
The sentence may also be changed by the transformation, negativization.

Sentence: The dog did not bite John.

\[ S = NP + Vt + NP \]

Both of these optional transformations represent changes from the basic kernel sentences and add complexity. For an individual that has not mastered Standard English, these changes may not be accurately decoded from the surface level to the deep structure intended by the sender. An individual may, for example, decode the passive form of the sentence as meaning "John bit the dog."

The transformational grammar model permits the comparison of language comprehension and production by deaf persons to that of the hearing population (who have mastered Standard English) in terms of the qualitative use of language structures. In general, deaf persons learn the more general phrase structure rules but have great difficulty learning the subtle manifestations in surface structure. Hearing impaired learners acquire the phrase structure rules to produce basic kernel sentences, but they have difficulty acquiring Standard English rules for expanding noun and verb phrase constituents which involve transformations. Quigley, Montanelli, and Wilbur (1975) noted that deaf subjects frequently misused auxiliaries and had difficulty with progressives, perfectives, questions and negations.

In summary, it can be seen that deaf students have considerable difficulties mastering many subtle aspects
of the use of the determiner and auxiliary systems of English, and that as many as 30 to 40 percent of them leave school not having gained control of their use in Standard English constructions. However, the broad aspects of word order and word use come under increasing control and are mastered reasonably well by many deaf children by the age of 12 (Russell, Quigley & Power, 1976, p. 69).

The most apparent differences between the linguistic skills of deaf and hearing persons are evident at the surface level and indicate differences in the use of transformational rules, which delete, insert, or transpose elements to produce a new or different surface structure. Quigley and Paul (1984) summarized the transformational rules according to the order of increasing difficulty as listed below:

1. Negation
2. Conjunction
3. Question-Formation
4. Pronominalization
5. Verb (Auxiliaries and Tense)
6. Complementation
7. Passivization and Relativization

In the following section each of these transformations will be described in comparison to "kernel" sentences, highlighted with an example, and discussed in terms of how the deaf acquire each.
Also included will be the transformation referred to as Transposition, in which no words are added or deleted, but the order is changed.

Listed below are the kernel sentence patterns that constitute the basics of Standard English. A notational key is provided at the bottom of the list for interpretation.

1. NP + Vi  
   The boy ran.
2. NP + Vi + Adv  
   The boys walked slowly.
3. NP + Vi + SubComp  
   John felt silly.
4. NP + Vt + NP  
   John chased the dog.
5. NP + Vt + NP + Adv  
   The cat followed the girls to school.
6. NP + Vt + NP + NP  
   The girls gave Libby the cat.
7. NP + Vt + NP + ObjComp  
   Paul called Gary a sissy.
8. NP + Ve + Adj  
   Paul is very brave.
9. NP + Ve + Adv  
   The fish is in the tank.
10. NP + Ve + NP  
    The shark is a big fish.
11. NP + Ve + Adj + Adv  
    Nancy was tired of school.
12. NP + Ve + NP + Adv  
    She was a student in school.

Notational Key:

NP = Noun Phrase
Vi = Verb intransitive (does not take an object)
Vt = Verb transitive (takes an object)
Ve = Verb equative
Adj = Adjective
Adv = Adverb
SubComp = Subject Complement
ObjComp = Object Complement
Transformational rules delete, insert or transpose elements to produce a new or different surface structure. Often this involves the modification of the basic kernel sentence.

Negation transformations involve the addition of negative adverbs or adjectives, as well as possible deletions of words or the addition and deletion of suffixes or prefixes. The form of the negation may be on the surface (no or not), or may be implied by the use of particular words.

Kernel: The man believed it.
Adverb negation (surface): The man did not believe it.
Adverb negation (implied): The man could scarcely believe it.
Adjective negation (surface): No man believed it.
Adjective negation (implied): Few men believed it.

Negation transformations may involve the incorporation of indefinites (any, anyone, anywhere, etc.), quantifiers (some, someone, etc.), or negative prefixes (im-, un-, dis-, etc.). Negation transformations are frequently associated with question-formation transformations.

Hearing children acquire the use of the negation transformational rule through a series of stages (Klima & Bellugi-Klima, 1966). In the first stage, children simply place "no" or "not" before a
clause or sentence (e.g., "no drink milk"). In the second stage, the negative element, including negated auxiliaries and models (e.g., can't, didn't, etc.) may be included within the sentence (e.g., "Mommy no drink milk"). In the third and final stage in which mastery is achieved production parallels the adult model. This third stage usually occurs by the age of eight.

The acquisition of the negation transformation by the hearing impaired learner is very similar to the stages that normal hearing individuals pass through. However, deaf learners acquire this rule at a much slower rate (Quigley, Montanelli & Wilbur, 1974). Negation is typically the easiest transformational rule for the deaf learner to master (Quigley & Paul, 1984).

Conjunction transformations are generated by the joining of sentences using "or", "and", or "but". Conjunctions may involve conjoined sentences, noun phrases, verb phrases, verbs, adverbs, or adjectives.


Conjoined sentence: Amy eats cookies but Gabe eats candy.

While most hearing children master conjunction transformations by the age of eight, deaf continue to make numerous errors in conjoining various grammatical structures, even at the age of 18 (Wilbur, Quigley & Montanelli, 1975). Conjunctions using "and" were generally mastered before "or" and "but" conjunctions for deaf subjects.
Question-formation transformations involve not only the deletion, addition or transposition of elements, but also involve the factors of question type and phonetic intonation. Declarative statements may be converted to interrogative questions by intonation alone or by the addition of elements.

**Kernel:** Mark eats cookies.
**Intonation question:** Mark eats cookies?
**Addition question:** Did Mark eat cookies?

The above examples demonstrate yes-no question types and are characterized by subject-auxiliary inversion. "WH-questions" begin with "who", "what", "when" or "where", and may be answered with a noun phrase or prepositional phrase. WH- questions may involve the deletion, addition, or transposition of elements, or additional transformations (in the example below, pronominalization). Questions may also take the form of How questions, Tag questions, or questions embedded within statements.

**Kernel:** Terri threw the cookie to the dog.
**Question transformation:** What did she throw to the dog?

**Kernel:** You bake cookies.
**How question transformation:** How do you bake cookies?
**Tag question transformation:** You bake cookies, don't you?
**Embedded question transformation:** Mike wondered if you bake cookies.
Although the full range of English question forms is highly complex, most are mastered by hearing children by the age of nine (C. Chomsky, 1969). Quigley, Wilbur & Montanelli (1975) reported that 10-year-old hearing subjects demonstrated nearly 100% correct responses on tests evaluating the understanding of most question forms, and were superior to the performance of 18-year-old deaf subjects. As with negation transformations, the differences are in rate of mastery rather than sequence.

Pronominalization transformations are the process by which pronouns are substituted for noun subjects, objects, or possessives. The term "person" refers to the relationship between the speaker and the person being spoken about. The following list of personal pronouns are in third person singular:

- **Kernel:** Les kicked Libby's ball over the fence.
- **Subject:** He kicked Libby's ball over the fence.
- **Object:** Les kicked it over the fence.
- **Possessive:** Les kicked her ball over the fence.

- **Kernel:** Lisa kicked the ball to Lisa.
- **Reflexive:** Lisa kicked the ball to herself.

Wilbur, Montanelli and Quigley (1975) concluded that most hearing children master the pronoun system by age ten. Just like their hearing counterparts, deaf children find possessive pronouns and reflexives to be the most difficult to master. Subject and object case pronouns are the easiest to master. However, deaf
learners demonstrate profound "delays" in the acquisition and use of pronominalization transformations (Russell, Quigley & Power, 1976).

Verb auxiliaries and tense changes also challenge the deaf learner attempting to master Standard English. Verb transformations often involve the addition and transposition of elements, and can imply conditional actions.

Kernel: Kim ran to the store. (past)
Verb tense: Kim will run to the store. (future)
Auxiliary: Kim may run to the store. (conditional)
Tense & Auxiliary: Kim may have run to the store. (past conditional)

The hearing impaired also experience delays in the acquisition and use of verb auxiliaries and tenses. The subtle nature of this particular transformation makes it difficult to decode the deep structure meaning regarding time or intent.

Complementation transformations involve the embedding of sentences which function as noun phrases in the subject or object position, or as the complement of a preposition. Other forms of complementations include extrapositions, subject-raising, and equi-noun deletions. The complementations will only be mentioned due to their complexities.

Object: The jury found that the butler did it.
Subject: To be found innocent was the butler's desire.
Preposition: The judge was surprised at the jury's decision to convict the butler.
Hearing children must master two primary concepts in order to learn the complement system of English: (a) the form of the three types of complements including optional deletion and extrapositional rules, and (b) the types of complements that can be taken by various classes of verbs. Most of these complements are learned through exposure to an oral/aural English model, and are mastered by the age of ten (Russell, Quigley & Power, 1976). Taylor (1969) analyzed the written production of deaf subjects and noted that complement structures are poorly understood, even by age 18.

Passivization transformations apply to noun phrase constituents. A sentence may appear at the surface level in either active or passive form. The sentences have different grammatical subjects and objects at the surface level, while at the deep structure level the logical subjects and objects are identical.

Kernal (active): The dog chased Ashley.
Passivization transformation: Ashley was chased by the dog.

The use of the passive voice is relatively difficult for hearing children to learn, but it is usually mastered by age nine (Turner & Rommeteveit, 1967). Fraser, Bellugi and Brown (1963) noted that the active voice involves straight left-to-right processing of subject-verb-object (S-V-O) word order. Passive voice changes the typical order to object-verb-subject (O-V-S) word order.
Initially, deaf children process the passive voice incorrectly according to the S-V-O word order. However, deaf learners continue to persist in the incorrect processing of the passive voice until a much later age than their hearing peers. Although this situation improves with age, even at age 18 nearly 40% of the deaf population persist in interpreting passive sentences according to the S-V-O word strategy (Power & Quigley, 1973). "Many deaf children appear not to have grasped the meaning implications of passive voice markers up to 10 years after the point at which virtually all hearing children have done so." (Russell, Quigley & Power, 1976, p. 96).

Relativization transformations involve the process of embedding sentences within other sentences. A relative clause contains one of the relative pronouns (who, whom, which or that).

Kernel sentences: The man flew the airplane. The man had blond hair.

Relativization: The man who had blond hair flew the airplane.

Basically, the process of relativization involves two steps. First, the identical noun in the embedded sentence is replaced by a relative pronoun. Secondly, the relative pronoun is moved to the front of the embedded sentence and the clause is embedded within the other sentence. Relative clauses may be placed either in the middle of a sentence (medial clause) or at the end of a sentence (final clause).
Quigley, Smith and Wilbur (1974) observed that 83% of their 10-year-old hearing subjects could correctly respond to various test items dealing with relativization transformations. Deaf subjects (age 18-19) produced only 76% correct responses. They concluded that the older deaf subjects continued to process in terms of the S-V-O word order strategy.

Finally, Transposition transformations involve the movement of adverbs or adverb phrase constituents from the typical final position to another position at the surface level.

Kernel: Greg drove the car on Thursday morning.
Transposition: On Thursday morning, Greg drove the car.

In summary, the transformational generative grammar model permits the researcher to systematically analyze the syntactical variables of the English language with a view towards determining which transformational rules are the most difficult for the deaf learner to master. Although most deaf individuals comprehend and produce the basic kernel patterns of Standard English, few are able to master the complex transformations and subtle nuances of the language.

Many researchers have a tendency to describe the hearing impaired learner as "delayed" in their acquisition of Standard English. The notion of a "language delay" is misleading. A language delay implies that the learner can and will "naturally" progress through a developmental sequence given sufficient stimulus input and
opportunity to practice. The English language is a spoken language. As such, English is primarily an oral-aural language. Deaf persons do not have ready access to the primary form of the language (phonemes). At best, the hearing impaired learners have access to the secondary form of the language which is printed or written. In written form, the oral-aural phonemes are merely represented. Fingerspelling is a tertiary form of the English language because it merely represents a letter which, in itself, is a representation. At best, the hearing impaired learner is expected to learn a phonetic-based language without the ability to receive or process the language in its primary form.

The notion of a "language delay" also ignores the fact that Standard English is not the native language of an hearing impaired individual. In essence, the hearing impaired learners are expected to learn a foreign language that is processed very differently from American Sign Language.

A "language delay" can only exist if the learner has access to the primary form of the language. To be truly "language delayed" for Standard English requires hearing. The learning of a secondary or tertiary form of a foreign language should not, therefore, be regarded as a delay.

Vocabulary knowledge is an important variable that influences reading ability. Many studies of vocabulary development confirm that deaf subjects comprehend far fewer printed words than hearing
subjects. The distribution and variability of word classes (nouns, verbs, etc.) is also less than hearing individuals as measured by type-token ratio (Fusaro & Slike, 1979; Griswold & Cummings, 1974; Hatcher & Robbins, 1978; Myklebust, 1960).

Hatcher and Robinson (1978) found that the primary word analysis skills of deaf subjects were unexpectedly low when compared to their vocabulary and reading skill development. Deaf subjects did not use the phonetic attack skills as hearing individuals did, which explained this difference.

Quigley and Paul (1984) noted that the average 8-year-old hearing subject scored higher than 18-year-old deaf subjects on tests evaluating the ability to comprehend Standard English syntax.

This would indicate a serious reading problem based on syntax alone. And when the typical vocabulary, conceptual, and experimental problems of deaf students are added, it would seem that commonly used reading materials might present serious reading difficulties for many deaf students. (Quigley & Paul, 1984, p. 122).

The use of figurative expressions in written and spoken language also present difficulties for deaf individuals. Conley (1976) found that when matched according to reading level, deaf and hearing subjects performed similarly on tests of figurative (idiom) comprehension up to the third grade reading level. Significant differences were found above this level favoring the hearing subjects. Deaf students can be instructed to counteract this

Discourse refers to the effects of surrounding text upon the comprehension of words or sentences, as compared to comprehension of words or sentences in isolation. Ewolt (1981) analyzed the reading skills of four prelingually deaf children and concluded that the deaf subjects were able to read and retell stories written in Standard English by interpreting the story into their own sign language. Although able to acquire a general idea of the meaning of the text, the deaf subjects lacked a complete understanding and misinterpreted important details. These results suggest that deaf individuals utilize a "top-down" approach to reading. The "top-down" approach is characterized by a reliance on prior knowledge rather than the exacting, detailed sequential decoding of printed language, referred to as the "bottom-up" approach. "Poor readers" rely on "top-down" strategies while good readers can employ either strategy depending on their familiarity with the content or the complexity of vocabulary and syntax.

Reading materials for young children generally control vocabulary complexity and semantic content. The variable of syntactic complexity remains unchanged from the adult model. Usually, only sentence length is controlled for (Hatch, 1969).
Transformational rules are usually not considered in the development of reading materials. This lack of concern for syntactic complexity is based upon the widely accepted but erroneous assumption that children have already internalized all of the structures of Standard English before entering school (Hatch, 1969; C. Chomsky, 1969). Deaf children have an even greater disadvantage in this respect (Quigley, Smith & Wilbur, 1974). Complex transformations frequently appear in the reading materials that are for instruction with hearing impaired students. Unfortunately, many of these transformations are not mastered by the deaf reader.

Passive transformations are typically introduced in first grade reading texts and increase in frequency with successive books (McKee, Harrison, McCowen, Lehr & Durr, 1966). Newspapers have a high incidence of passive transformations, especially on the front page (Power, 1971). Relativization transformations also appear in reading primers (McKee, et al., 1966).

Yes-No and WH-question-formation transformations appear in both primers and first grade readers (Quigley, Wilbur & Montanelli, 1974). McKee, et al. (1966) also noted that conjunction transformations are presented early in reading texts. Conjoined noun and verb phrases occur in first primers, while conjoined sentences and adjectives are introduced in first grade readers. Russell, Quigley and Power (1976) noted that pronominalization
transformations occurred in all eleven books of the Houghton-Mifflin series, Reading for Meaning.

Complementation transformations increase from 4 per 100 sentences at the second primer level to 62 per 100 sentences at the sixth grade level. Materials with frequent complementation transformations are extremely difficult to use with the deaf and require extensive modification (Russell, Quigley & Power, 1976).

Even by the age of 18, deaf individuals have difficulty with the transformations frequently found in standard reading materials. Only recently have specially prepared reading materials been designed which control for the variable of transformational rule usage. Currently no text materials are available which control for transformations and vocabulary in the content areas of science, social studies or mathematics. Thus, deaf students are frequently denied instruction comparable to hearing students because of these limitations.

Information Input: Pictorial

"The basic question in instruction is how to proceed in order to facilitate the acquisition of essential background information by individuals who have not had the opportunity to benefit from first-hand experience." (Dwyer, 1978, p. 4). Instructional approaches typically rely heavily upon verbal representations of this "first-hand experience" in the form of lecture or written material, supplemented by pictures. Various realism theories have
suggested that learning is more complete as the number of cues increase. This implies the increased utilization of methods and materials to supplement verbal-based instruction.

The strategy most commonly practiced to alleviate the need for concrete personal experience and to facilitate student learning has been to integrate visual materials, illustrating relevant content information, into the teaching-learning process to complement both oral and printed instruction (Dwyer, 1978, p. 4).

Dale's Cone of Experience (1946), Osgood's More Detachable-Less Detachable Continuum (1953), and Morris' Iconicity Theory (1946) all represent realism theories suggesting that learning is facilitated by increasing the realism and life-like qualities of instructional stimuli. Realism theories contend that an increase in cues will result in an increase in learning, therefore highlighting the need for visual stimuli.

The ability to share knowledge through verbal techniques is a skill of inestimable benefit to humans, and its value cannot be reasonably disputed in or out of the classroom. Verbalization, however, is not the only mode through which we can learn. The emphasis on reading and writing in our educational system suggests that verbalization is prerequisite to all learning, and, perhaps, to most communication. The long experience of mankind suggests otherwise... that the visualization of information can
be invaluable to helping the communicator/teacher teach and the audience/learner learn, and can be so whether it is used alone or accompanied by verbal information (Wileman, 1980, pp. 15-16).

We are more comfortable as verbal, rather than visual, communicators because we are trained in the use of verbalization from our earliest days through constant exposure to the spoken or written word. Wileman (1980) noted that our communication patterns are shaped not only by society in general but by our training in school, which has long been dominated by verbalization as the emphasized means of sharing information.

Despite the fact that we see our world more than we speak or read of it, we are rarely trained in the use of visualization (i.e., communicating messages visually). As a result, our ability to communicate is limited, for we must be as familiar with the visual realm as with the verbal if we are to communicate the richness of our experience and the complexity of our knowledge. (Wileman, 1980, p. 16).

Extensive research has been conducted with hearing subjects regarding the use of visual methods of instruction. Dwyer (1972) concluded that illustrations facilitated the comprehension and retention of information presented verbally. Hartman (1961) compared printed verbal, pictorial, and combined verbal/pictorial, and found that the combined format was the most effective when
the mode of evaluation remained consistent with the mode of presentation. Booher (1973) compared various pictorial and word combinations and found that the best overall results for task accuracy and task completion time were achieved with a highly pictorial format accompanied by related print.

The rationale for visual instruction is well documented by many realism theorists (Carpenter, 1953; Dale, 1964; Gibson, 1954; Knowlton, 1964; Morris, 1946; Osgood, 1953). Visual messages have many desirable features that are important for learning. Visual messages can be attention-getting (the first step for instruction), efficient (quick and bold in hastening comprehension), effective (focus on particular aspects), concrete and lasting, and their visual-spatial nature can complement the temporal-sequential nature of verbal information.

Dwyer (1978) described many of the potential benefits of visually communicated instruction:

1. Increased interest and concentration.
2. Provides instructional feedback.
3. Improves perception of objects, processes or situations from various vantage points.
4. Facilitates information retention.
5. Spans linguistic barriers.
6. Increases the reliability of communication.
7. Brings inaccessible processes, events, situations and materials into the classroom.
8. Quantifies relationships and specifies details.
9. Illustrates abstract concepts or spatial relationships.
10. Overcomes time and distance.
11. Introduces, organizes and presents new information.
12. Functions to integrate facts, skills and judgments.

Wileman (1980) described the range of messages that can be communicated visually:

1. Concrete Data (e.g., types of energy resources).
2. Directions (e.g., how to make bread).
3. Processes (e.g., steel making).
4. Bits of Data (e.g., racial make-up of Mexico).
5. Comparative Data (e.g., drug usage by age).
6. Data Recorded over Time (e.g., rainfall in Ohio, 1900-1985).
7. Organizational Structures (e.g., U.S. State Department).
8. Places (e.g., city map or floor plan).
9. Chronologies (e.g., history of flight).
10. Generalizations (e.g., national investment potential).
11. Theories (e.g., Maslow's Holistic-Dynamic Theory).
12. Feelings or Attitudes (e.g., love).

Wileman (1980) described three basic categories of symbols for representing ideas or concepts: (a) pictorial symbols, (b) graphic symbols, and (c) verbal symbols. Pictorial symbols are highly concrete and realistic, such as 3-D models, sculpture, photographs, or detailed drawings. Pictorial symbols are relatively easy for the viewer to transfer meaning from the symbol to reality.
Graphic symbols may be divided into three basic groups, image-related, concept-related or arbitrary (Modley, 1970). Image-related graphic symbols are two-dimensional and highly recognizable, such as a silhouette or profile. Concept-related graphic symbols are more stylized and less detailed. Concept-related graphic symbols present the essence of the object. Arbitrary graphic symbols are visually unrelated to the object and are often an abstracted symbol for the object or concept, such as the red geometric shape chosen to represent the message "stop" to a driver. Arbitrary symbols are the result of the designer's imagination and are often judged aesthetically.

Verbal symbols may include letters, words, or sentences which require verbal competence. Verbal symbols may be either labels or definitions.

Wileman (1980) placed these three groupings of symbols on a "realism" continuum (Figure 1).

Wileman's Continuum of Visual Symbols

Concrete <-> Abstract
Easy to decode         Difficult to decode

Pictorial Symbols  Graphic Symbols  Verbal Symbols

Figure 1.
The choice of symbols depends upon the communication objectives, information content, and audience ability or interest. The designer of educational messages should be adept at designing visual materials with symbols from any point on the continuum according to viewer need.

The goal of the communicator/teacher is to either select or develop appropriate visual materials to improve instruction. Although many books on graphic art are available, few are designed to help the educator develop well-planned visual materials. The potential for the use of visuals in the classroom has yet to be fully realized. Wileman (1980) noted that although many visual instruction materials are available to the teacher, most are poorly conceptualized or integrated.

Combining Verbal and Pictorial Input

Visual instructional materials should be designed to complement verbal instruction while capitalizing upon student learning style and processing strengths (Dwyer, 1978). Wileman (1980) described the complex relationship between verbal images (words) and visual images (pictures) for developing instructional materials. He cautioned that projected verbal images (such as words or text projected by an overhead projector) are not necessarily "visual aides." Wileman (1980) developed a seven-step continuum to describe the relationship between verbal and visual components that may be used to develop an instructional "slide".
The "Type 1" visual is referred to by Wileman (1980) as a "Reader Slide". Type 1 visuals require verbal literacy and can be used to outline or summarize ideas. Type 1 visuals may involve the variation of typeface, layout, or colors. Figure 2 is an example of a Type 1 visual.

Example of a Type II Visual: Emphasized Reader Slide (purely verbal)

Rain (precipitation) falls to the earth and collects in lakes or streams. This water evaporates by the heat of the sun and becomes water vapor. Finally, the water vapor cools and condenses to form clouds.

Figure 2

Type II visuals also require verbal literacy, but add the variables of changing typeface, the use of upper or lower case, stars, asterisks or color to highlight particular aspects of the message. Figure 3 is an example of a Type II, or "Emphasized Reader" slide.

Example of a Type II Visual: Emphasized Reader Slide

Rain (precipitation) falls to the earth and collects in lakes or streams. This water evaporates by the heat of the sun and becomes water vapor. Finally, the water vapor cools and condenses to form clouds.

Figure 3
Type III visuals are still predominately verbal, but add pictorial or graphic symbols to focus the viewer's attention and supplement the verbal information presented. Information is presented in a linear, sequential manner. Figure 4 presents an example of a Type III visual.

Example of a Type III Visual: Reader Slide

With Visual Cues to Meaning

Rain (precipitation) falls to the earth and collects in lakes or streams.

This water evaporates by the heat of the sun and becomes water vapor.

Finally, the water vapor cools and condenses to form clouds.

Figure 4

Type IV visuals are "balanced" as to the relationship between verbal and pictorial components. The "Visual-Verbal Balanced Slide" requires both verbal literacy and visual literacy. Information may be presented in either a linear or spatially-oriented display. Figure 5 presents a Type IV visual with spatially-oriented display.
Example of a Type IV Visual: Verbal/Visual

Balanced Slide

Type V visuals are primarily pictorial in design with words functioning as labels to orient the viewer. This type of visual requires the viewer to be more competent with visual literacy. Often Type V visuals are used to present complex ideas or numerical data. Information is typically presented in a spatially-oriented display such as a diagram. Figure 6 presents an example of a Type V visual.
Example of a Type V Visual: Pictorial or Graphic Symbol Slide with Verbal Cues to Meaning

Figure 6

Type VI visuals do not employ any verbal information. Arrows, geometric shapes, color, and texture are design variables that the designer may use to focus attention. The viewer relies entirely upon visual literacy to decode and extract information. Figure 7 is an example of a Type VI visual.
Example of a Type VI Visual: Emphasized Pictorial or Graphic Slide

Type VII visuals are purely pictorial and are typically photographs, detailed illustrations or simple graphics. Detailed or highly realistic Type VII visuals demand visual literacy from the viewer and often require technical skill to develop. This type of visual is very common to instructional texts and functions to augment the verbal information presented in the text. Many of these highly detailed visuals merely decorate the page if the viewer fails to understand the text and relate it to the picture. Figure 8 presents an example of a Type VII visual.
Example of a Type VII Visual: Pictorial or Graphic Symbol Slide (purely pictorial)

Figure 8

Wileman's Verbal-Visual Continuum (1980) provides an excellent model for designing the pictorial components of printed instructional formats. These pictorial components can then be combined with text to produce a format that meets the learner's needs for pictorial and verbal complexity. By combining Wileman's Verbal-Visual Continuum with Chomsky's Transformational Generative Grammar, the educator can evaluate or design instructional formats that capitalize upon the processing strengths of the learner.

Previous Studies

Relatively few research projects have compared the comprehensibility of various methods of presenting information in
a printed format with hearing impaired subjects. However, numerous studies have research this question with normal hearing subjects.

Dwyer (1972) conducted a series of studies on the use of pictorial materials in enhancing the effectiveness of instructional presentations. He found that the effectiveness of illustrations frequently depended upon the type of information to be presented, but that overall, illustrations facilitate comprehension and retention. His work also suggested that line drawings are frequently more effective for instruction than detailed drawings or photographs, particularly in situations where instructional time is limited or externally paced.

Hartman (1961) compared the instructional effectiveness of various forms of "multiple channel communication". The study compared the combined and separate presentations of information presented by pictorial and print "channels". His results indicated that the pictorial channel alone may produce better comprehension of information than the print channel alone. Hartman (1961) found that multiple channel presentations were generally more effective than single channel presentations, particularly when the tests of comprehension employed the same information channels as the presentations.

Mehrabian and Reed (1968) also noted that the effectiveness of multiple channel instruction is dependent upon the learner's perceptual and cognitive characteristics which enable him to receive and interpret information conveyed through various channels. "The
information in the print channel must employ a level of vocabulary and language complexity compatible with the student's reading achievement level and linguistic competence" (Reynolds & Rosen, 1973, p. 4). This observation is particularly appropriate and essential when applied to the hearing impaired learner.

Booher (1973) conducted a study to compare the relative comprehensibility of pictorial information and printed words in instructions. His subjects were required to complete a set of operational procedures on a control-display panel. His results indicated that a multiple channel format with a high degree of pictorial information combined with related print information produced the best overall results in terms of task accuracy and time. Booher (1973) also suggested that the use of pictorial information in presenting instructions can be an important factor for completing concrete operational tasks.

Reynolds and Rosen (1973) conducted a study to compare the effectiveness of textbook, individualized and pictorial instructional formats with hearing impaired college students. Their study was based on the hypothesis that a pictorial presentation format should facilitate the acquisition and retention of information for hearing impaired students because it relies less heavily on the verbal-print channel.

In the study, three different printed instructional formats were prepared which presented "essentially the same information"
(Reynolds & Rosen, 1973, p. 6) on the topic of introductory information on neuroanatomy and physiological psychology. The textbook format presented information in a narrative form that was considered by the researchers to be typical of many textbooks. The vocabulary and grammatical structure were judged subjectively to be "somewhat less complex than would usually be found in a college level text." (Reynolds & Rosen, 1973, p. 9). The verbal text consisted of 700 words. The pictorial component consisted of eight line drawings with printed words and labels to orient the viewer. Arrows connected these verbal labels with the corresponding part of the brain depicted in the line drawing.

The individualized format contained many of the features of individualized instruction, specifically printed learning objectives, self-test questions and the opportunity for active responses by the viewer. The individualized format was composed of 1,100 words and was "similar to the narrative used in the textbook format, although in some cases sentence structure was simplified." (Reynolds & Rosen, 1973, p. 9). The individualized format also included nine line drawings.

The pictorial format "presented as much of the information as possible in the form of line drawings and figures" (Reynolds & Rosen, 1973, p. 10). The text consisted of brief descriptive phrases or sentences, and totalled 300 words. This format presented the viewer with 26 line drawings.
The study involved two experiments. A total of 52 hearing impaired students enrolled at the Gallaudet College Preparatory program participated in the first experiment which investigated comprehension. The second experiment investigated retention and involved 94 subjects from the same program at Gallaudet. All subjects had an average norm-referenced reading score equivalent to a seventh or eighth grade reading level.

A posttest was prepared to assess comprehension and retention, and included matching questions to verify comprehension of function, location and description of different parts of the brain. A pretest composed of matching and multiple choice questions was prepared to estimate prior knowledge of the topics.

In the first experiment, designed to investigate comprehension, subjects were randomly assigned to one of the three format groups. Subjects were given the pretest followed by the appropriate instructional packages. Subjects were told to study the materials carefully to prepare for a test on the material. Although no time limit was placed on the study session, all subjects finished within the one-hour period. The following day subjects completed the posttest during a one-hour period. Although no time limit was placed on the session, all subjects completed the posttest well before the end of the session.

In the second experiment, designed to assess retention as well as comprehension, subjects were again randomly assigned to one of
the three format groups. During the first session, subjects completed the pretest and studied the material during a one-hour period. The posttest was administered during a one-hour period 13 days after the first session.

The median percent correct scores on the pretest differed slightly but not significantly among the three format groups for both experiments. The researchers concluded that the pretest scores supported the assumption that the three format groups were comparable in their level of understanding of the subject matter prior to reading the instructional materials.

For experiment 1, the pictorial group achieved a median score of nearly 80% correct, while the individualized and textbook groups scored 68% and 66%, respectively. The pictorial group score was significantly higher than the textbook group at the .05 level. All other group differences were not significantly different.

The median posttest scores for the second experiment were considerably lower for each of the format groups when compared to the first experiment. These differences were statistically significant (p < .001) when comparing the first and second experiment scores as a composite. The researchers suggested that this result reflected the decay in retention over a longer interval between study and posttest.

The results of the second experiment did, however, produce a similar trend among the format groups. The pictorial group again
achieved the highest score among the three groups, although none of the group differences were significantly different at the .05 level.

Reynolds and Rosen (1973) then compared gain scores calculated from the pretest scores and the posttest questions from which the pretest was taken. In both experiments, the gain scores for the pictorial group were higher than the gain scores for the other two groups. In the second experiment assessing retention, the pictorial format gain score was significantly higher ($p < .02$) than the gain score for the textbook format.

The researchers concluded that "information presented to hearing impaired students by a pictorial format with relatively brief verbal descriptions, can produce significantly better comprehension of information than a more verbal textbook style of presentation." (Reynolds & Rose, 1973, p. 15). This trend in favor of the pictorial format also appeared to persist after a period of 13 days between instructional presentation and posttest. Gain scores also supported the conclusion that the pictorial presentation was the most effective instructional format for the students in the experiment. The experiments demonstrated the "importance of presenting information in a form that is compatible with the information processing capabilities of the student." "The explicitness and clarity of a pictorial presentation can be especially effective with hearing impaired and/or linguistically deficient students." (Reynolds & Rosen, 1973, p. 19).
Reynolds and Booher (1980) compared performance time and accuracy on various operational tasks by college level deaf subjects in response to different instructional formats. Four sets of instructions were prepared which described the operational procedures for completing tasks on a programmable task simulator, developed by Booher initially for the training of U.S. Navy personnel assigned to mechanical/electrical responsibilities. The researchers hypothesized that instructional formats consisting primarily of pictures would produce better task performance than would formats consisting entirely or largely of printed verbal information. Similar to Booher's (1973) results, they expected that an instructional format consisting of a high proportion of pictures and a lower proportion of related printed verbal information would produce both superior task completion time and error rate. Four instructional formats were developed to investigate the variables of printed verbal and pictorial informations: All Pictorial, All Verbal, High Pictorial-Low Verbal, and High Verbal-Low Pictorial.

The All Pictorial format consisted of information presented through outline drawings with no printed verbal information. Labels on the simulator consisted only of alphanumeric symbols. The pictures depicted the general areas of the simulator, the specific controls, displays or tables to be referred to, and the sequence of the actions to be performed.
The All Verbal format consisted entirely of printed verbal and numeric information "arranged in complete, but relatively simple, sentences and paragraphs." This format did not include any pictures. Printed verbal labels were used on the simulator.

The High Pictorial-Low Verbal format used the same diagrams from the All Pictorial format, but added some related printed words and phrases. These words and phrases included labels to identify specific controls, displays and tables shown in the drawings, and "brief descriptions of the action-steps to be followed." Like the All Verbal format, printed verbal labels were used on the simulator.

Lastly, the High Verbal-Low Pictorial format consisted of the same printed verbal information contained in the All Verbal format with some related diagrams. These outline drawings included word labels that were connected by arrows to specific controls and displays.

Subjects were assigned at random to one of the four instructional format groups. Each subject was seated individually in front of the simulator and was provided with a typed set of instructions. The instructions described the purpose of the experiment, described the various parts of the apparatus, and described the specific operations to be executed on the simulator. These instructions were also summarized by the experimenter in sign language followed by an opportunity to ask questions.

Three practice sessions were given for location and reference orientation. After the practice opportunities, subjects completed
eight experimental tasks which alternated location and reference tasks. Performance was measured in terms of error rates and completion times for each task. Tasks involved a series of steps from which the experimenter could record errors in completion of ordering, and time required to complete each task. Error data was calculated as a percentage of the total number of steps for the tasks. Time data was calculated from the average completion time per problem.

Analysis of variance was employed to analyze time and error data according to problem type. There were significant effects between instructional formats for time scores ($F = 6.32, p < .01$), but differences between problem types and the format x problems interaction were not significant. Error data yielded significance between instructional format ($F = 3.47, p < .05$) and problem types ($F = 6.12, p < .05$), but a non-significant interaction between these factors.

The All Pictorial format yielded the shortest mean task completion times, with longer completion times for the High Pictorial-Low Verbal format, and substantially higher time scores for the All Verbal and High Verbal-Low Pictorial groups. Multiple comparisons indicated that the All Pictorial produced significantly shorter task completion than either the All Verbal or the High Verbal-Low Pictorial formats for both Location and Reference problems.

The lowest error rates were produced by the High Pictorial-Low Verbal format, with slightly higher error rates for the All Verbal
format and substantially higher error rates for the All Pictorial format. Considering both time and error data, the All Pictorial format yielded the shortest mean task times but relatively high error rates. The High Pictorial-Low Verbal format produced the lowest error rate and the second shortest task completion times. "Therefore, with both performance measures considered, the High Pictorial-Low Verbal format emerged as the most effective instructional design." (Reynolds & Booher, 1980, p. 182).

In summary, the previous studies support the notion that formats present the hearing impaired learner with "simplified" English and pictorial diagrams are the most effective for instruction. In general, pictorial information requires little or no "decoding" or interpretation by subjects. Verbal labels tend to facilitate orientation and understanding of the relationship among the pictorial components. Verbal information, on the other hand, must be decoded and interpreted according to the rules of Standard English in order to derive meaning. Since the hearing impaired learner typically learns the basic patterns of the English language by systematic instruction, it follows that instructional formats should utilize those basic patterns and avoid the more complex patterns of the language that are not mastered.
Designing Instructional Materials

The studies conducted by Reynolds and Rosen (1973) and Reynolds and Booher (1980) identified the most important factors of printed formats intended for deaf learners: the length and complexity of printed text in Standard English and the use of pictorial images to communicate information. The designer must determine the optimal length and complexity of the printed text and the design of the pictorial elements.

Reynolds and Rosen (1973) described the quantitative length of the three formats in their study in terms of total number of words but described the qualitative aspects of the text in more general terms. For example, the 700-word textbook format was designed with vocabulary and grammatical structures that were "judged subjectively to be somewhat less complex than would usually be found in a college level text." (Reynolds & Rosen, 1973, p. 9). The 1,100 word individualized format was "similar to the narrative used in the textbook format, although in some cases sentence structure was simplified." (Reynolds & Rosen, 1973, p. 9). Finally, the 300-word text of the pictorial format consisted of "brief descriptive phrases or sentences" (Reynolds & Rosen, 1973, p. 10). Although the researchers did focus attention upon the variable of linguistic complexity, replication of study will be somewhat limited by the non-specific description of the text components.

Reynolds and Rosen (1973) provided one-page examples of all three formats in their appendices. All three formats included
Type V visuals, which involve pictorial symbol slides with verbal cues to meaning (Wileman, 1980). The textbook format example included negation, conjunction, verb auxiliary, complementation and relativization transformations. The individualized format example included negation, conjunction, question-formation and relativization transformations. The pictorial format example included only one sentence that contained a single conjunction transformation. From the examples provided, it would appear that differences did exist among the formats in terms of variety and type of transformations, length of each sentence, and possibly variety of words used.

Reynolds and Booher (1980) also described the qualitative aspects of the four instructional formats of their study in rather general terms. The All Pictorial format contained no printed verbal information. The All Verbal format "consisted entirely of printed verbal and numerical information arranged in complete, but relatively simple, sentences and paragraphs." (Reynolds & Booher, 1980, p. 180). The High Pictorial-Low Verbal format was designed to use the same diagrams as the All Pictorial format "with the addition of some related printed words and phrases" (Reynolds & Booher, 1980, p. 180). The High Verbal-Low Pictorial format "consisted primarily of the same verbal information used in the All Verbal format" (Reynolds & Booher, 1980, p. 180).
In both of the above studies, the results indicated that the combination of simplified text and pictorial diagrams are the foundation for the most effective instructional formats for use with the hearing impaired learner. Specifically, the verbal aspects of an instructional format should be designed to control for the qualitative factors of variety of vocabulary (Type-Token Ratio), frequency of transformations (Percentage of Transformations) and type of transformations, as well as the quantitative aspects of total number of words and average length of sentences (Mean Length Utterance). Likewise, the pictorial aspects of a particular format should specifically describe design principles.
CHAPTER 3
METHODOLOGY

This study used the methodology of experimental research to investigate the effects of various printed instructional formats on the comprehension of academic content information. The design of the study is similar to the study by Reynolds and Rosen (1973) which compared three printed instructional formats in terms of information comprehension and retention for college-level deaf subjects.

Subjects

Sixty prelingually deaf subjects, ages 12 to 22, whose onset of hearing loss occurred before the mastery of speech or the age of two, took part in the study. Subjects had a pure tone hearing loss of 85 dB or greater in the better ear (ANSI) with no other documented handicapping conditions, and measured IQ scores within the normal range.

The subjects were drawn from the Ohio School for the Deaf, the Columbus (Ohio) Public Schools' hearing impaired program, and the Zanesville (Ohio) City Schools' hearing impaired program. Table 1 shows the distribution of subjects by sex and the average age and reading level as measured by the SAT-HI or Metropolitan reading tests.
Table 1
Mean age and reading level of subjects by sex

<table>
<thead>
<tr>
<th>Sex</th>
<th>n</th>
<th>Age</th>
<th>Reading Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>29</td>
<td>15.3</td>
<td>2.95</td>
</tr>
<tr>
<td>Female</td>
<td>31</td>
<td>15.9</td>
<td>3.94</td>
</tr>
</tbody>
</table>
Subjects were randomly assigned to one of the four instructional format groups. Table 2 shows the group means for age and reading level.

Table 2
Mean age and reading level of subjects by format groups

<table>
<thead>
<tr>
<th>Format</th>
<th>n</th>
<th>Age</th>
<th>Reading Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Text</td>
<td>15</td>
<td>15.9</td>
<td>3.43</td>
</tr>
<tr>
<td>Males</td>
<td>7</td>
<td>16.6</td>
<td>3.11</td>
</tr>
<tr>
<td>Females</td>
<td>8</td>
<td>15.3</td>
<td>3.71</td>
</tr>
<tr>
<td>Simplified Text</td>
<td>14</td>
<td>16.1</td>
<td>3.81</td>
</tr>
<tr>
<td>Males</td>
<td>7</td>
<td>16.4</td>
<td>2.37</td>
</tr>
<tr>
<td>Females</td>
<td>7</td>
<td>15.7</td>
<td>5.24</td>
</tr>
<tr>
<td>Simplified Text/Labeled Diagram</td>
<td>16</td>
<td>14.9</td>
<td>3.19</td>
</tr>
<tr>
<td>Males</td>
<td>7</td>
<td>14.6</td>
<td>2.60</td>
</tr>
<tr>
<td>Females</td>
<td>9</td>
<td>15.1</td>
<td>3.66</td>
</tr>
<tr>
<td>Labeled Diagram</td>
<td>15</td>
<td>15.7</td>
<td>3.48</td>
</tr>
<tr>
<td>Males</td>
<td>8</td>
<td>15.8</td>
<td>3.65</td>
</tr>
<tr>
<td>Females</td>
<td>7</td>
<td>15.7</td>
<td>3.30</td>
</tr>
</tbody>
</table>
Materials

Four printed instructional formats employing different combinations of verbal text, pictures and labeling were developed for comparison. These formats were compared to determine their effects upon the comprehension of science content by hearing impaired readers ages 12 to 22.

Content for the instructional formats was drawn from a commercially produced science textbook designed for use with hearing students at the sixth grade level. Specifically, the content involved the water cycle and the carbon dioxide-oxygen cycle.

Each of the four instructional formats included both pictorial and verbal components. The four instructional formats were referred to as (1) the Standard Text format, (2) the Simplified Text format, (3) the Simplified Text/Labeled Diagram format, and (4) the Labeled Diagram format.

Each format contained either Type VII or Type IV visuals (Wileman, 1980). The Type VII visuals were incorporated for the Standard Text and Simplified Text formats. Type VII visuals are typically detailed line drawings, illustrations or photographs that do not contain any verbal labeling or other symbols such as arrows or numbers to orient the viewer. Two Type VII visuals were used for the Standard Text and Simplified Text formats, and were facsimiles of the two illustrations presented in the commercially prepared textbook which served as a design model.
The Simplified Text/Labeled Diagram and Labeled Diagram formats employed Type IV visuals. Type IV visuals are "balanced", in that both pictorial and verbal information is presented to the viewer. The verbal information involved words, phrases, short sentences, alphanumeric symbols and arrows to orient the viewer to the important information or concepts depicted in the picture. Type IV visuals typically involve line drawings or illustrations that are less detailed than Type VII visuals. However, for this study the Type IV and Type VII visuals involved line drawings. Twenty diagrams with verbal labeling were designed for the Simplified Text/Labeled Diagram format and the Labeled Diagram format.

The verbal elements of the experimental formats can be divided into three categories: (a) standard text, (b) simplified text, and (c) verbal labeling for diagrams. The standard text was copied directly from the commercially prepared textbook and included many of the transformations generated in Standard English. Only the Standard Text format used this category of verbal element.

Two of the instructional formats utilized the simplified text component: the Simplified Text and Simplified Text/Labeled Diagram formats. The Simplified Text component was prepared by reducing the complexity of the standard text. Basically, the text was rewritten with a view towards reducing the number of complex transformations. Sentences which contained complex transformations were rewritten in basic "kernel" sentence form and followed the
less complicated subject-verb-object word order. The text was simplified according to transformational grammar principles to parallel the twelve kernel sentence patterns that constitute the basics of English.

Lastly, the verbal labeling for diagrams involved the use of alphanumeric symbols, words, phrases or simplified sentences to orient the reader to information contained in the accompanying diagram. Two of the instructional formats utilized the verbal labeling for diagrams: the Simplified Text/Labeled Diagram and Labeled Diagram formats.

These three verbal elements were described and compared quantitatively by a process known as Mean Length Utterance (MLU). Mean Length Utterance describes the average length of each word, phrase or sentence that is presented as a thought or utterance (referred to as a "unit" in Table 3). Table 3 compares the mean length utterance (MLU) of the three verbal components.

Quantitatively, the standard text presented the reader with the longest units or sentences to decode. The simplified text presented the reader with much shorter sentences. The verbal labeling for diagrams presented the shortest MLU due to the frequency of single words or short phrases.

Type-Token Ratio (TTR) is a qualitative measure which describes the variety of words used according to word classification (i.e., noun, verb, preposition, etc.) and usage. Table 4 compares the
Table 3

Mean length utterance of verbal components.

<table>
<thead>
<tr>
<th></th>
<th>Words</th>
<th>Units</th>
<th>MLU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard text</td>
<td>504</td>
<td>44</td>
<td>11.5</td>
</tr>
<tr>
<td>Simplified text</td>
<td>383</td>
<td>69</td>
<td>5.6</td>
</tr>
<tr>
<td>Verbal labeling for diagrams</td>
<td>217</td>
<td>95</td>
<td>2.3</td>
</tr>
</tbody>
</table>
## Table 4

*Type-Token Ratio of verbal components*

<table>
<thead>
<tr>
<th></th>
<th>Words</th>
<th>Usages</th>
<th>TTR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard text</td>
<td>504</td>
<td>186</td>
<td>37%</td>
</tr>
<tr>
<td>Simplified text</td>
<td>383</td>
<td>111</td>
<td>29%</td>
</tr>
<tr>
<td>Verbal labeling for diagrams</td>
<td>217</td>
<td>58</td>
<td>27%</td>
</tr>
</tbody>
</table>
Type-Token Ratio of the three verbal components. Type-Token Ratio is a measure of linguistic variety and complexity at the word level.

The standard text required the reader to have the largest reading vocabulary of the three verbal components. Although the variety of usages (TTR) was similar for the remaining two components, the verbal labeling for diagrams component had far fewer usages for the reader to master when compared to the simplified text component. The standard text presented the most complex of the three verbal components at the word level.

At the sentence level, linguistic complexity can be described by counting the frequency and type of transformations that appear in each verbal component. Table 5 lists the frequency of transformations that appear in each component.

The standard text was the most complex at the sentence level with 93% of the sentences containing at least one transformation. Further analysis indicated that the standard text had 23 sentences with more than one transformation while the simplified text had only one sentence with more than one transformation. Table 6 summarizes the additional complexities of multiple transformations within sentences. The verbal labeling for diagrams component did not contain any sentences with transformations, and is therefore not listed in Table 6.

As a final qualitative measure, transformation types were tallied to determine the number of particular transformations that
Table 5

Frequency and percentage of transformations in verbal components

<table>
<thead>
<tr>
<th></th>
<th>Total Sentences</th>
<th>Sentences with Transformations</th>
<th>Percentage with Transformations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard text</td>
<td>44</td>
<td>41</td>
<td>93%</td>
</tr>
<tr>
<td>Simplified text</td>
<td>69</td>
<td>13</td>
<td>19%</td>
</tr>
<tr>
<td>Verbal labeling for diagrams</td>
<td>6</td>
<td>0</td>
<td>0%</td>
</tr>
</tbody>
</table>
Table 6

Frequency and percentage of sentences with multiple transformations for verbal components

<table>
<thead>
<tr>
<th>Multiple Transformations</th>
<th>Standard Text</th>
<th>Simplified Text</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two</td>
<td>12 (27%)</td>
<td>1 (1%)</td>
</tr>
<tr>
<td>Three</td>
<td>7 (16%)</td>
<td></td>
</tr>
<tr>
<td>Four or More</td>
<td>4 (9%)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>23 (52%)</td>
<td>1 (1%)</td>
</tr>
</tbody>
</table>
were contained in the verbal components. Table 7 lists the transformation types and frequency of occurrence.

Tables 3 through 7 summarize the quantitative and qualitative differences in linguistic complexity among the three verbal components. Each of the four formats combined one or more verbal components with a pictorial component. The pictorial components were line drawings produced with an Apple Macintosh computer using the software package MacPaint. The verbal labeling was also produced with the MacPaint software. The pictures and diagrams were then combined with the text components which were produced with the word processing package MacWrite.

The Standard Text format combined the standard text with two Type VII visuals. The text and pictorials for this format were copied from a sixth grade science text. The Standard format comprised two printed pages with 504 words, 44 units (sentences) and two line drawings which did not include any verbal labeling or visual cues to meaning.

The Simplified Text format combined the reduced transformational text with two Type VII visuals. This format comprised three printed pages with 383 words, 69 units (sentences) and two line drawings which were identical to the Standard Text format pictorials.

The Simplified Text/Labeled Diagram format combined the simplified text with twenty Type IV visuals that included verbal labeling for the diagrams. This format comprised nine printed pages.
Table 7

Frequency of transformational types for verbal components

<table>
<thead>
<tr>
<th>Transformation Type</th>
<th>Standard Text</th>
<th>Simplified Text</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negation</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Conjunction</td>
<td>25</td>
<td>3</td>
</tr>
<tr>
<td>Question-Formation</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Pronominalization</td>
<td>25</td>
<td>0</td>
</tr>
<tr>
<td>Verbs (Auxiliary or Tense)</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Complementation</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Passivization</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Relativization</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Phrase Order (Adverb)</td>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total Transformations</strong></td>
<td><strong>85</strong></td>
<td><strong>13</strong></td>
</tr>
</tbody>
</table>
The Simplified Text included 383 words in 69 units (sentences). The verbal labeling for the diagrams included 217 words in 95 units (words, phrases, and sentences) for a total of 600 words and 164 units (MLU = 3.7).

The Labeled Diagram format presented twenty Type IV visuals without any accompanying text. The visuals did include verbal labeling for the diagrams totaling 217 words in 95 units (words, phrases, and sentences).

All formats are presented in Appendix A. Table 8 summarizes the verbal and pictorial content of the four formats.

A 37 item posttest was prepared to evaluate the subjects' comprehension of the information content. The posttest was designed to cover virtually all of the substantive information presented in the four instructional formats as did the posttest design implemented by Reynolds and Rosen (1973). The posttest included (a) matching terms to short definitions, (b) matching terms to a picture, (c) matching short phrases to a pictures, and (d) multiple choice questions. The pretest consisted of five term/definition matching items and five multiple choice questions drawn from the posttest. The pretest provided the means to compute gain scores and to determine prior knowledge of the information content. The pretest and posttest are presented in Appendix B.

Procedure

Each of the four instructional formats served as a level of the independent variable. Gain scores calculated from the pretest
Table 8

Verbal and pictorial content of formats

<table>
<thead>
<tr>
<th>Format</th>
<th>Verbal</th>
<th>Pictorial</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Words</td>
<td>Units</td>
</tr>
<tr>
<td>Standard Text</td>
<td>504</td>
<td>44</td>
</tr>
<tr>
<td>Simplified Text</td>
<td>383</td>
<td>69</td>
</tr>
<tr>
<td>Simplified Text/Labeled Diagram</td>
<td>600</td>
<td>164</td>
</tr>
<tr>
<td>Labeled Diagram</td>
<td>217</td>
<td>95</td>
</tr>
</tbody>
</table>
and posttest differences served as a measure of the dependent variable, comprehension. Sex and reading level (as measured by the SAT-HI or Metropolitan reading tests) functioned as intervening variables that influenced the relationship between the independent and dependent variables.

The study took place during May, 1986, at the Ohio School for the Deaf, Columbus Public Schools, and Zanesville City Schools. The study was conducted during regularly scheduled periods at the Columbus and Zanesville locations. The study was conducted on a weekday evening at the residential Ohio School for the Deaf, due to parental concern regarding instructional time during school hours.

The study was designed to be administered during 45-minute periods so as to simulate a regular instructional period typically found in school programs and to reduce the novelty of a non-standard routine. The external pacing also functioned to parallel the time-controlled environment of standardized reading comprehension testing.

The study took place in well lighted classrooms with the classroom teacher in attendance to insure on-task behavior. The testing at the Ohio School for the Deaf was completed in a well-lighted multi-purpose room supervised by two residential coordinators. Students were seated at individual desks in the Columbus and Zanesville settings while subjects were seated by twos at long folding tables at the residential school.
Prior to each session, directions were printed on a chalkboard and pretests were placed face down on each desk or station with a sharpened pencil. The experimenter gave the instructions in simultaneous spoken and signed modes. The protocol and instructions printed on the chalkboard are listed in Appendix C. The experimenter referred to the printed instructions on the chalkboard during the five minute introduction period. These instructions presented in a chart form the three phases of the session: (a) a short test requiring five minutes; (b) a study period of fifteen minutes; and (c) a test period of ten minutes.

Following instructions and questions, subjects were directed to turn over their pretest, fill in their name on the cover, and begin the test. Subjects were encouraged by the experimenter to review their work in the event they completed their task and turned their papers face down prior to the end of the time period. All subjects easily completed the pretest within the five minute time period.

At the end of the five minute period the experimenter collected and labeled each pretest to indicate which format was randomly assigned to each subject. The instructional formats were arranged before each session in sequential order to ensure random distribution. After labeling the pretest for each subject, the instructional format was placed face down on the subject's desk. After all pretests were collected, the experimenter repeated the instructions to study the material for fifteen minutes. Following any questions
from the subjects, the experimenter directed subjects to turn over their respective formats and begin studying. As with the pretest, subjects were encouraged by the experimenter to review their formats in the event they "completed" their tasks prior to the end of the allotted fifteen minutes. All subjects "finished" studying the material within the allotted time.

Following the study period, the experimenter collected the formats and again referred to the chart on the chalkboard to review the directions for the posttest. All subjects completed the posttest within the ten minute time period. At the end of the posttest time, the experimenter collected the posttests and pencils, and checked each posttest to ensure complete names were provided.

Hypotheses

Comprehension will improve as syntactic complexity is simplified and Type VII visuals are replaced by Type IV visuals. The four experimental formats are listed below in order of expected levels of comprehension as indicated by group mean gain scores:

1. Simplified Text/Labeled Diagram format
2. Simplified Text format
3. Labeled Diagram format
4. Standard Text format

The experimenter hypothesized that the simplified text will have a greater effect upon gain scores than the pictorial diagram, thus the preference for the Simplified Text format over the Labeled Diagram format.
Assumptions

1. Performance on a printed test is a valid means for assessing comprehension.

2. Subjects will attend to printed stimuli (verbal or pictorial) according to learning style preference and comprehension.

3. Randomization and prompting will ensure equity among groups in regards to effort.

Statistical Analyses

Various statistical models were tested to determine which combination of variables had the greatest influence upon the dependent variable, gain score. Analysis of covariance was used to compare the mean gain scores among treatment groups while making statistical adjustments to compensate for group differences in sex and reading level. Age and IQ produced only a minimal effect upon gain scores, singly or in combination with other variables, and therefore were not included in the statistical model.

Analysis of covariance is a "marriage" of regression analysis and the analysis of variance (Hopkins & Glass, 1978) permitting comparisons between and among treatment groups. Mean gain scores were adjusted based upon the regression model accounting for sex and reading level.

Statistical Hypotheses (null)

1. Main effect: The mean gain scores among treatment groups will be the same.

(a) $H_0: \mu_1 = \mu_2 = \mu_3 = \mu_4 \ (p < .05)$
2. Individual format effects: The mean gain score for each treatment group will be equal to zero.

   (a) Ho2: \( \mu_1 = 0 \) (\( p < .05 \))
   (b) Ho3: \( \mu_2 = 0 \) (\( p < .05 \))
   (c) Ho4: \( \mu_3 = 0 \) (\( p < .05 \))
   (d) Ho5: \( \mu_4 = 0 \) (\( p < .05 \))

3. Between group differences: The mean gain scores between treatment groups will be the same.

   (a) Ho6: \( \mu_1 = \mu_2 \) (\( p < .05 \))
   (b) Ho7: \( \mu_1 = \mu_3 \) (\( p < .05 \))
   (c) Ho8: \( \mu_1 = \mu_4 \) (\( p < .05 \))
   (d) Ho9: \( \mu_2 = \mu_3 \) (\( p < .05 \))
   (e) Ho10: \( \mu_2 = \mu_4 \) (\( p < .05 \))
   (f) Ho11: \( \mu_3 = \mu_4 \) (\( p < .05 \))

4. Individual format effects (by sex): The mean gain scores for each treatment will be equal to zero for either sex.

   **Males**
   (a) Ho12: \( \mu_1 = 0 \) (\( p < .05 \))
   (b) Ho13: \( \mu_2 = 0 \) (\( p < .05 \))
   (c) Ho14: \( \mu_3 = 0 \) (\( p < .05 \))
   (d) Ho15: \( \mu_4 = 0 \) (\( p < .05 \))

   **Females**
   Ho16: \( \mu_1 = 0 \) (\( p < .05 \))
   Ho17: \( \mu_2 = 0 \) (\( p < .05 \))
   Ho18: \( \mu_3 = 0 \) (\( p < .05 \))
   Ho19: \( \mu_4 = 0 \) (\( p < .05 \))
5. **Within sex differences:** The mean gain scores between treatments will be the same for comparisons within the dichotomous categories of sex.

<table>
<thead>
<tr>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) $H_{020}$: $\mu_1 = \mu_2$ ($p &lt; 0.05$)</td>
<td>$H_{026}$: $\mu_1 = \mu_2$ ($p &lt; 0.05$)</td>
</tr>
<tr>
<td>(b) $H_{021}$: $\mu_1 = \mu_3$ ($p &lt; 0.05$)</td>
<td>$H_{027}$: $\mu_1 = \mu_3$ ($p &lt; 0.05$)</td>
</tr>
<tr>
<td>(c) $H_{022}$: $\mu_1 = \mu_4$ ($p &lt; 0.05$)</td>
<td>$H_{028}$: $\mu_1 = \mu_4$ ($p &lt; 0.05$)</td>
</tr>
<tr>
<td>(d) $H_{023}$: $\mu_2 = \mu_3$ ($p &lt; 0.05$)</td>
<td>$H_{029}$: $\mu_2 = \mu_3$ ($p &lt; 0.05$)</td>
</tr>
<tr>
<td>(e) $H_{024}$: $\mu_2 = \mu_4$ ($p &lt; 0.05$)</td>
<td>$H_{029}$: $\mu_2 = \mu_4$ ($p &lt; 0.05$)</td>
</tr>
<tr>
<td>(f) $H_{025}$: $\mu_3 = \mu_4$ ($p &lt; 0.05$)</td>
<td>$H_{031}$: $\mu_3 = \mu_4$ ($p &lt; 0.05$)</td>
</tr>
</tbody>
</table>
CHAPTER 4
RESULTS

Table 9 depicts the main effect of format type. The analysis of covariance model adjusted group differences according to variances in reading level and sex.

Table 9
Analysis of covariance: Main effect
(a) Ho1: $\mu_1 = \mu_2 = \mu_3 = \mu_4$ (rejected @ .%)

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>ss</th>
<th>df</th>
<th>Mean Square</th>
<th>F-value</th>
<th>Prob &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between</td>
<td>11282.31</td>
<td>15</td>
<td>752.15</td>
<td>2.94</td>
<td>.0027</td>
</tr>
<tr>
<td>Within</td>
<td>11253.09</td>
<td>44</td>
<td>255.75</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The mean gain scores among treatment groups were statistically different, and therefore Hypothesis 1 was rejected at the .05 level. There appeared to be a main effect of format that accounted for differences among the four groups.

100
Individual group means were analyzed to determine if they differed significantly from what could be expected by mere chance (Ho: \( \mu = 0 \)). The mean gain scores and standard error of mean are presented in Table 10. As can be seen, the Simplified Text format yielded the highest mean gain score (18.15), followed by the Simplified Text/Labeled Diagram format (16.20), the Labeled Diagram format (15.68), and the Standard Text format (-3.35), respectively.

Table 10

Analysis of covariance: Individual format effects
(a) Ho2: \( \mu_1 = 0 \)
(b) Ho3: \( \mu_2 = 0 \)
(c) Ho4: \( \mu_3 = 0 \) (rejected @ .05)
(d) Ho5: \( \mu_4 = 0 \) (rejected @ .05)

| Format                          | \( n \) | Mean Gain Score | Standard Error | Prob > \(|T|\) Ho: \( \mu = 0 \) |
|---------------------------------|--------|----------------|----------------|-------------------------------|
| Standard Text                   | 15     | -3.35 (\( \mu_1 \)) | 4.24           | 0.43                          |
| Simplified Text                 | 14     | 18.15 (\( \mu_2 \)) | 10.53          | 0.09                          |
| Simplified Text/Labeled Diagram | 16     | 16.20 (\( \mu_3 \)) | 7.22           | 0.03                          |
| Labeled Diagram                 | 15     | 15.68 (\( \mu_4 \)) | 4.19           | 0.005                         |
The null hypothesis (H02: $\mu_2 = 0$) was accepted as tenable at the .05 level for the Standard Text format, which produced a negative mean gain score. Although the Simplified Text format yielded the highest gain scores, the null hypothesis (H03: $\mu_2 = 0$) was not rejected at the .05 level, due to the high standard error. Both the Simplified Text/Labeled Diagram and Labeled Diagram formats produced results that permitted the rejection of the null hypotheses (H04: $\mu_3 = 0$; H05: $\mu_4 = 0$, respectively) at the .05 level. Only the Simplified Text/Labeled Diagram and the Labeled Diagram formats produced gain scores that were significantly better than what could be expected by mere chance.

The group means were also compared to determine if any significant differences existed between individual formats (e.g., H0: $\mu_1 = \mu_2$). Table 11 presents the differences between individual treatment groups.

The Standard Text format and the Simplified Text format were not significantly different despite a 20-point difference in mean gain score. Again, the high standard error of the Simplified Text format influenced this result. The null hypothesis (H06: $\mu_1 = \mu_2$) was not rejected at the .05 level.

However, the Simplified Text/Labeled Diagram format yielded a mean gain score (16.20) that was significantly higher than the Standard Text format (-3.35). The null hypothesis (H07: $\mu_1 = \mu_3$) was rejected at the .05 level.
Table 11

Analysis of covariance: Between group differences

(a) $H_0^6: \mu_1 = \mu_2$
(b) $H_0^7: \mu_1 = \mu_3 \text{ (rejected @ .05)}$
(c) $H_0^8: \mu_1 = \mu_4 \text{ (rejected @ .05)}$
(d) $H_0^9: \mu_2 = \mu_3$
(e) $H_0^{10}: \mu_2 = \mu_4$
(f) $H_0^{11}: \mu_3 = \mu_4$

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Text (-3.35)</td>
<td>--</td>
<td>0.06</td>
<td>0.02</td>
<td>0.002</td>
</tr>
<tr>
<td>Simplified Text (18.15)</td>
<td>0.06</td>
<td>--</td>
<td>0.88</td>
<td>0.83</td>
</tr>
<tr>
<td>Simplified Text/ Labeled Diagram (16.20)</td>
<td>0.02</td>
<td>0.88</td>
<td>--</td>
<td>0.95</td>
</tr>
<tr>
<td>Labeled Diagram (15.68)</td>
<td>0.002</td>
<td>0.83</td>
<td>0.95</td>
<td>--</td>
</tr>
</tbody>
</table>
The Labeled Diagram format also yielded a higher mean gain score (15.58) than the Standard Text format. The null hypothesis (Ho8: μ1 = μ4) was rejected at the .05 level.

The Simplified Text, Simplified Text/Labeled Diagram and Labeled Diagram formats all produced mean gain scores that were not significantly different from each other. Accordingly, the null hypotheses (Ho9: μ2 = μ3; Ho10: μ2 = μ4; Ho11: μ3 = μ4) were accepted as tenable at the .05 level.

The mean gain scores between treatments were compared within the dichotomous categories of sex. This procedure permitted comparisons to determine which formats yielded the highest mean gain scores for male or female subjects. Although female subjects had overall higher mean gain scores (14.48) than male subjects (8.89), the difference was not significant (p < .43). Table 12 summarizes the mean gain scores for both male and female subjects.

For male subjects, the Standard Text, Simplified Text, and Simplified Text/Labeled Diagram formats did not yield mean gain scores that were significantly different from what would be expected by chance. The null hypothesis for each of these treatments was accepted (Ho12: μ1 = 0; Ho13: μ2 = 0; and Ho14: μ3 = 0). The null hypothesis for the Labeled Diagram format (Ho15: μ4 = 0) was rejected at the .05 level. For male subjects, only the Labeled Diagram format yielded a mean gain score significantly higher than what could be expected from chance alone.
Table 12
Mean gain scores for male and female subjects

<table>
<thead>
<tr>
<th>Format</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ho12: ( \mu_1 = 0 )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ho13: ( \mu_2 = 0 )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ho14: ( \mu_3 = 0 )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ho15: ( \mu_4 = 0 ) (rejected @ .05)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ho16: ( \mu_1 = 0 )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ho17: ( \mu_2 = 0 ) (rejected @ .05)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ho18: ( \mu_3 = 0 ) (rejected @ .05)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ho19: ( \mu_4 = 0 ) (rejected @ .05)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Format                  | Mean Gain Score | Standard Error | Prob > |T/ | Ho: \( \mu = 0 \) |
|------------------------|-----------------|----------------|---------|
| Standard Text          |                 |                |         |
| Males                  | 7               | -3.93 (\( \mu_1 \)) | 6.17    | 0.53 |
| Females                | 8               | -2.77          | 5.83    | 0.64 |
| Simplified Text        |                 |                |         |
| Males                  | 7               | 13.21 (\( \mu_2 \)) | 19.95   | 0.51 |
| Females                | 7               | 23.08          | 6.76    | 0.001 |
| Simplified Text/Labeled Diagram |         |                |         |
| Males                  | 7               | 11.46 (\( \mu_3 \)) | 13.37   | 0.40 |
| Females                | 9               | 20.93          | 5.43    | 0.0004 |
| Labeled Diagram        |                 |                |         |
| Males                  | 8               | 14.69 (\( \mu_4 \)) | 5.70    | 0.01 |
| Females                | 7               | 16.67          | 6.15    | 0.0009 |
For female subjects, the Standard Text format yielded a mean gain score that was not significantly different from chance. Therefore, the null hypothesis (H016: \( \mu_1 = 0 \)) was accepted as tenable. However, the Simplified Text, Simplified Text/Labeled Diagram and Labeled Diagram formats all produced mean gain scores that were significantly higher than what could be expected by chance at the .05 level. The null hypotheses (H017: \( \mu_2 = 0 \); H018: \( \mu_3 = 0 \); and H019: \( \mu_4 = 0 \)) were all rejected for female subjects.

The mean gain scores between individual treatments were compared within the categories of sex to determine if the differences were significant. Tables 13 and 14 summarize these comparisons. Table 13 presents the between group differences for male subjects.

For male subjects, the Labeled Diagram format yielded significantly higher mean gain scores than the Standard Text format. The null hypothesis (H022: \( \mu_1 = \mu_4 \)) was rejected at the .05 level. The null hypotheses were not rejected for all other group comparisons.

The Labeled Diagram format yielded the highest mean gain score (14.69), followed by the Simplified Text (13.21), Simplified Text/Labeled Diagram (11.46), and Standard Text (-3.93) formats, respectively.

Table 14 summarizes the between group differences for females. For female subjects, the Simplified Text, Simplified Text/Labeled Diagram, and Labeled Diagram formats yielded significantly
Table 13

Analysis of covariance: Between group differences for males

(a) \( H_{o20}: \mu_1 = \mu_2 \)
(b) \( H_{o21}: \mu_1 = \mu_3 \)
(c) \( H_{o22}: \mu_1 = \mu_4 \) (rejected @ .05)
(d) \( H_{o23}: \mu_2 = \mu_3 \)
(e) \( H_{o24}: \mu_2 = \mu_4 \)
(f) \( H_{o25}: \mu_3 = \mu_4 \)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Text (-3.93)</td>
<td></td>
<td>0.41</td>
<td>0.30</td>
<td>0.03</td>
</tr>
<tr>
<td>Simplified Text (13.21)</td>
<td>0.41</td>
<td></td>
<td>0.94</td>
<td>0.94</td>
</tr>
<tr>
<td>Simplified Text/ Labeled Diagram (11.46)</td>
<td>0.30</td>
<td>0.94</td>
<td></td>
<td>0.83</td>
</tr>
<tr>
<td>Labeled Diagram (14.69)</td>
<td>0.03</td>
<td>0.94</td>
<td>0.83</td>
<td></td>
</tr>
</tbody>
</table>
Table 14

Analysis of covariance: Between group differences
for females

(a) $H_0^{26}: \mu_1 = \mu_2$ (rejected $@ .05$)  
(d) $H_0^{29}: \mu_2 = \mu_3$

(b) $H_0^{27}: \mu_1 = \mu_3$ (rejected $@ .05$)  
(e) $H_0^{30}: \mu_2 = \mu_4$

(c) $H_0^{28}: \mu_1 = \mu_4$ (rejected $@ .05$)  
(f) $H_0^{31}: \mu_3 = \mu_4$

<table>
<thead>
<tr>
<th>I/J</th>
<th>Standard Text (-2.77)</th>
<th>Simplified Text (23.08)</th>
<th>Simplified Text/Labeled Diagram (20.93)</th>
<th>Labeled Diagram (16.67)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Text (-2.77)</td>
<td>--</td>
<td>0.006</td>
<td>0.005</td>
<td>0.03</td>
</tr>
<tr>
<td>Simplified Text (23.08)</td>
<td>0.006</td>
<td>--</td>
<td>0.81</td>
<td>0.49</td>
</tr>
<tr>
<td>Simplified Text/Labeled Diagram (20.93)</td>
<td>0.005</td>
<td>0.81</td>
<td>--</td>
<td>0.61</td>
</tr>
<tr>
<td>Labeled Diagram (16.67)</td>
<td>0.03</td>
<td>0.49</td>
<td>0.61</td>
<td>--</td>
</tr>
</tbody>
</table>
higher mean gain scores than the Standard Text format. However, these three formats were not significantly different from one another. For female subjects, the Simplified Text format yielded the highest mean gain score (23.08), followed by the Simplified Text/Labeled Diagram (20.93), Labeled Diagram (16.67), and the Standard Text formats, respectively.

Table 15 summarizes the rank order of format mean gain scores for all subjects, male and female.

Table 15
Overall rank order of format mean gain scores

<table>
<thead>
<tr>
<th>All Subjects</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Simplified Text</td>
<td>18.15</td>
</tr>
<tr>
<td>2. Simplified Text/Labeled Diagram</td>
<td>16.20*</td>
</tr>
<tr>
<td>3. Labeled Diagram</td>
<td>15.68*</td>
</tr>
<tr>
<td>4. Standard Text</td>
<td>-3.35</td>
</tr>
</tbody>
</table>

* mean significantly different from chance (Ho: μ = 0)
Table 16 summarizes the rank order of format mean gain scores for male subjects and female subjects.

Table 16

<table>
<thead>
<tr>
<th>Rank order of format mean gain scores by sex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
</tr>
<tr>
<td>1. Labeled Diagram</td>
</tr>
<tr>
<td>14.69*</td>
</tr>
<tr>
<td>2. Simplified Text</td>
</tr>
<tr>
<td>13.21</td>
</tr>
<tr>
<td>3. Simplified Text/Labeled Diagram</td>
</tr>
<tr>
<td>11.46</td>
</tr>
<tr>
<td>-3.93</td>
</tr>
</tbody>
</table>

* indicates mean significantly different from chance 
(Ho: μ = 0)

A final series of statistical analyses were performed intended to further identify the importance of individual design elements. Although not part of the testable hypotheses, information from the following analyses can provide impetus for future research concerning specific design components for instructional format studies. Interpretation of these results should be cautious.
since each format was not specifically designed to control for each of these interrelated variables in a systematic manner. Analyses of covariance were implemented to determine the main effects of Mean Length Utterance, Type-Token Ratio, the total number of words found in each format, the total percentage of sentences with transformations, and the total number of pictures contained in each format.

Table 17 depicts the main effect of the linguistic variable Mean Length Utterance, or average number of words contained in each sentence, phrase, or printed language unit.

The mean gain scores among the treatment groups were significantly different at the .05 level indicating the main effect of Mean Length Utterance. This finding would suggest the importance of this linguistic variable for instructional format purposes. Since the variable was not specifically controlled in the design of the format and due to the lack of control for the other linguistic variables, the importance of Mean Length Utterance can only be suggested.

Table 18 depicts the main effect of the linguistic variable Type-Token Ratio, or variety of words presented in each format.

The mean gain scores among the treatment groups were significantly different at the .05 level indicating the main effect of Type-Token Ratio. Type-Token Ratio would appear to be a critical design component for the development of instructional formats intended for use with hearing impaired learners.
Table 17

Analysis of covariance: Main effect of Mean Length Utterance

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>ss</th>
<th>df</th>
<th>Mean Square</th>
<th>F-value</th>
<th>Prob &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between</td>
<td>6956.34</td>
<td>3</td>
<td>2318.78</td>
<td>8.34</td>
<td>.0001</td>
</tr>
<tr>
<td>Within</td>
<td>15579.06</td>
<td>56</td>
<td>278.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Source of Variation</td>
<td>ss</td>
<td>df</td>
<td>Mean Square</td>
<td>F-value</td>
<td>Prob &gt; F</td>
</tr>
<tr>
<td>--------------------</td>
<td>--------</td>
<td>----</td>
<td>-------------</td>
<td>---------</td>
<td>----------</td>
</tr>
<tr>
<td>Between</td>
<td>6089.20</td>
<td>3</td>
<td>2029.73</td>
<td>6.91</td>
<td>.0005</td>
</tr>
<tr>
<td>Within</td>
<td>16446.20</td>
<td>56</td>
<td>293.68</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 19 summarizes the main effect of the quantitative linguistic variable total number of words within each instructional format.

The mean gain scores among the treatment groups were not significantly different at the .05 level, indicating that the main effect of total number of words within each instructional format was not significant among the formats despite the external pacing of the task. Although not appearing to be significant in this study, further research which controls for the other linguistic variables could indicate the importance of this design variable.

Table 20 presents the statistical data for the main effect of the qualitative linguistic variable of the total percentage of sentences or phrases which contain transformations.

The mean gain scores among the treatment groups were significantly different at the .05 level, indicating that the main effect of total percentage of sentences with transformations was a significant design variable.

Lastly, Table 21 presents the statistical information regarding the main effect for the pictorial/linguistic variable of the total number of pictures contained in each format.

The mean gain scores among the treatment groups were again significantly different at the .05 level indicating the main effect of total number of pictures. The number and type of pictorial information appears to be a critical design element for the
Table 19

Analysis of covariance: Main effect of total number of words

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>ss</th>
<th>df</th>
<th>Mean Square</th>
<th>F-value</th>
<th>Prob &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between</td>
<td>2799.78</td>
<td>3</td>
<td>933.26</td>
<td>2.65</td>
<td>.057</td>
</tr>
<tr>
<td>Within</td>
<td>19735.62</td>
<td>5</td>
<td>352.42</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 20

Analysis of covariance: Main effect of total percentage of sentences with transformations

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>ss</th>
<th>df</th>
<th>Mean Square</th>
<th>F-value</th>
<th>Prob &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between</td>
<td>7194.12</td>
<td>3</td>
<td>2398.04</td>
<td>8.75</td>
<td>.0001</td>
</tr>
<tr>
<td>Within</td>
<td>15341.28</td>
<td>56</td>
<td>273.95</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 21

Analysis of covariance: Main effect of total number of pictures

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>ss</th>
<th>df</th>
<th>Mean Square</th>
<th>F-value</th>
<th>Prob &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between</td>
<td>4472.63</td>
<td>3</td>
<td>1490.88</td>
<td>4.62</td>
<td>.006</td>
</tr>
<tr>
<td>Within</td>
<td>18062.77</td>
<td>56</td>
<td>322.55</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
development of instructional formats for use with deaf learners.

In summary, the linguistics elements of Mean Length Utterance, Type-Token Ratio, and total number of sentences with one or more transformations appear to be critical design components that can enhance the comprehension of information content for hearing impaired readers. The total number of pictures and type also appear to significantly effect the comprehension of instructional content. Although not significant at the .05 level, the variable of total number of words did appear to be a variable that could be of importance given the .057 level found in the analysis of covariance. From the above model, the order of statistical effect yields the following ranking of design effects:

1. Total percentage of sentences with transformations.
2. Mean Length Utterance.
3. Type-Token Ratio
4. Total number of pictures.
5. Total number of words.
CHAPTER 5

GENERAL DISCUSSION

The purpose of this study was to investigate the feasibility of circumventing or supplementing instructional methods which over-emphasize verbal-based learning approaches for use with the hearing impaired learner. Specifically, this study compared the effects of varying combinations of printed verbal information and pictorial content contained in instructional formats on the comprehension of science content by hearing impaired subjects.

Four printed instructional formats employing various combinations of verbal and pictorial elements were prepared based upon content drawn from a commercially produced science textbook designed for the sixth-grade level reader. The four instructional formats presented the same information regarding the water cycle and carbon dioxide-oxygen cycle. These formats were referred to as (a) the Standard Text format, (b) the Simplified Text format, (c) the Simplified Text/Labeled Diagram format, and (d) the Labeled Diagram format.

The Standard Text format was developed by reproducing the text and pictures found in a commercially prepared textbook designed for sixth grade science students. The verbal text included the
complex transformations found in the original and was accompanied by two line drawings without verbal labeling.

The Simplified Text format differed from the Standard Text format by simplifying the printed text. This process involved the rewriting of the text to reduce the number of transformations, reducing the total number of words, reducing the average length of each sentence, and decreasing the variety of words used. These changes were based upon principles derived from transformational generative grammar theory. The two line drawings found in the Standard Text format were retained.

The Simplified Text/Labeled Diagram format presented the reader with the same simplified text found in the Simplified Text format but the two line drawings were replaced with twenty labeled diagrams. The viewer could access information from either the text or the diagrams. The diagrams were designed according to pictorial information theory developed by Wileman (1980).

The Labeled Diagram format was developed by removing the accompanying text from the Simplified Text/Labeled Diagram format. The twenty labeled diagrams were retained.

All four formats were developed to investigate the variables of standard and simplified text, and line drawings and labeled diagrams. All materials were produced on a MacIntosh computer using the MacWrite word processing software and the MacPaint graphic software.
Sixty prelingually deaf subjects, ages 12 to 22, participated in the study. Each subject had a sensori-neural hearing impairment of 85dB (ANSI) or more in the better ear for the speech frequency range (500, 1000, 2000 Hz). The hearing loss occurred prior to the age of two for all subjects. All subjects had to have a measured IQ within the normal range and no other documented handicapping conditions.

Subjects were randomly assigned one of the four instructional formats which served as levels of the independent variable. Gain scores were calculated from a ten item pretest and a 37 item posttest. The gain scores served as a measure of the dependent variable, comprehension.

Analyses of the data included comparisons among the mean gain scores for the four instructional format groups, and comparisons of the gain scores were performed for male and female subjects independently. The statistical procedure chosen for the comparisons was analysis of covariance. The analysis of covariance model used adjusted the mean gain scores to compensate for differences in sex and reading level among the treatment groups.

Two basic assumptions guided the selection of hypotheses for the study. First, it was assumed that hearing impaired subjects would evidence better comprehension when presented with verbal text that was simplified and contained fewer complex language patterns than the standard text. Second, it was assumed that an increase
Results showed that the best instructional formats for both male and female subjects combined were the Simplified Text/Labeled Diagram format and the Labeled Diagram format. Both formats produced significantly higher mean gain scores when compared to the Standard Text format. Although the Simplified Text format also produced a higher mean gain score than the Standard Text format, the mean gain score was not significantly different from the other three formats.

Differences did exist between male and female subjects in terms of reading level, gain score variability, mean gain score, and relative effectiveness of formats. Although not significant at the .05 level, female subjects had a higher average reading level (3.94 v. 2.95) and higher mean gain score (14.48 v. 8.89), and less variability among scores (3.03 standard error v. 6.36) than male subjects.

For female subjects, the Simplified Text, Simplified Text/Labeled Diagram, and Labeled Diagram formats all yielded gain scores that were significantly better than what could be expected by chance alone. These three formats were also significantly better than the Standard Text format in terms of mean gain scores.

The relative effectiveness of instructional formats differed for male subjects. The Labeled Diagram format was the only format
to produce significantly higher mean gain scores than could be expected by chance, and significantly higher gain scores than the Standard Text format. The high variability among the scores prevented significant differences among the other formats for male subjects.

Since the combined results are consistent with previous studies conducted with deaf subjects, the research has general implications for the design of instructional materials developed for the education of hearing impaired learners. The research work also highlights differences in performance between male and female subjects suggesting different processing needs for instructional purposes.

The analysis of covariance for individual format effects for all subjects showed that only two formats produced gain scores that were significantly different from what could be expected by chance alone: the Simplified text/Labeled Diagram format and the Labeled Diagram format. The Simplified Text/Labeled Diagram format yielded a mean gain score of 16.20, significant at the .03 level while the Labeled Diagram format produced a mean gain score of 15.68, significant at the .005 level. These two formats were the only formats which presented complete information to the viewer via a spatially-oriented display, the labeled diagram. This result alone highlights the importance of the pictorial design element for the hearing impaired learner. The systematic application of
visual/pictorial design is probably the least understood and most overlooked medium of instruction for the deaf learner.

The Standard Text format was demonstrated to be an inappropriate format for effective instruction with the hearing impaired student, despite the fact that it was designed for a sixth grade level reader. Although the negative mean gain score (-3.35) should not be interpreted as "negative learning," the results clearly indicate that instructional formats which rely upon mastery of the complexities of the English language are not effective nor efficient for the typical hearing impaired learner. These results suggest that the use of standard textbooks is not a logical choice when attempting to select materials appropriate to the processing needs of the deaf student. These results support the position of Moores (1978) who stated that special instructional methods for use with deaf learners are lacking beyond specialized speech and language instruction. The subject areas of science, social studies, and other content areas are limited by the "language barrier" imposed by complex forms of Standard English and the inability to circumvent this barrier by education.

The Simplified Text format yielded the highest mean gain score of all the experimental formats (18.15). However, the high degree of variation (std. err. = 10.53) prevented this result from being significant at the .05 level. Close examination of Table 12 reveals that male subjects evidenced a much higher standard error than
female subjects for this format. Male subjects had a standard error of 19.95 while female subjects produced a standard error of 6.76. It is possible that replication of this study with another sample would result in less variation and permit the Simplified Text format to produce significantly higher mean gain scores than could be expected by chance. Statistically, this format was significant at the .06 level, which suggests that replication would be of value.

The Simplified Text/Labeled Diagram format produced the highest mean gain score that was significant at the .05 level of confidence. This format demonstrated the viability of presenting content information in both a simplified form of English and a pictorial mode that produced significant learning. The Simplified Text/Labeled Diagram format provides a means for presenting complex concepts and processes without relying on a prerequisite skill of complete mastery of the language. The results indicate that the transformational generative grammar model can be combined with visual design theory to provide the deaf learner with an appropriate instructional format.

The Labeled Diagram format demonstrated yet another viable format for instruction. Examination of Table 12 shows that this format was significant for both male and female subjects at the .05 level. Despite the "unorthodox" appearance of this format, the Labeled Diagram format is appropriate for the processing needs of
the hearing impaired learner. The results also support previous research that suggested that the hearing impaired learner can effectively process spatially-oriented displays of information.

Overall, the analyses of covariance for individual format effects supported the hypotheses that as syntactic complexity is reduced, comprehension should improve. The results also confirmed the hypotheses that as pictorial display increased and provided more cues to the viewer, comprehension would improve. The analyses of covariance for between group differences highlighted these trends.

Both the Simplified Text/Labeled Diagram and Labeled Diagram formats produced mean gain scores that were significantly better than the Standard Text format at the .05 level of confidence. The Simplified Text format produced a higher mean gain score than the Standard Text format, but the high variation nullified its significance. Differences among the Simplified Text, Simplified Text/Labeled Diagram, and Labeled Diagram formats were not significant at the .05 level.

The importance of simplifying the text is most obvious when comparing the differences between the Standard Text and the Simplified Text. Although the 21 point difference was not significant at the .05 level, the results do suggest that verbal complexity is a critical design variable. In this respect, the results support the studies by Reynolds and Rosen (1973) and Reynolds and Booher (1980),
as well as numerous transformational grammar studies that highlight the need for simplified language patterns for instruction with deaf students.

The second key design variable, visual type, produced significant mean gain scores for the two formats when the Type IV visuals were employed. The first two formats (Standard Text and Simplified Text) failed to produce significant mean gain scores, thus confirming the critical factor of visual type. A comparison between the Simplified Text and the Simplified Text/Labeled Diagram formats permits the control of the variable, verbal text complexity, and isolates the variable, visual type. Since only the Simplified Text/Labeled Diagram format produced a mean gain score significant beyond chance, the importance of the labeled diagram variable is emphasized. However, the direct comparison between the two formats yielded gain scores that were not significantly different. Further comparisons between these two formats in future studies is needed to determine the importance of the Type IV visual over the Type VII visual while controlling the text variable.

The analysis of covariance procedure was again used to determine if any differences existed between male and female subjects in terms of performance with each format. Differences would indicate not only the optimal format but also suggest differences in processing needs. The data showed that male and female subjects performed differently according to format type which suggests differences in processing modalities.
Although male subjects did produce lower mean gain scores for all formats, the differences were not significant when compared to female subjects. For male subjects, only one format produced a mean gain score significant beyond chance at the .05 level: the Labeled Diagram format. The Standard Text format produced a negative mean gain score (-3.93). Although not suggesting that the standard format produces "negative learning", this result does suggest that this highly verbal format with limited pictorial information is totally inappropriate for the processing needs of the male deaf learner in the study. The Simplified Text format did produce a positive mean gain score (13.21), but the high variation offset the significance of the score. At this point it is unclear if the process of simplifying the text is adequate to produce significant comprehension of material for male subjects. Replication of this study with another sample may clarify the effect of this variable. The Simplified Text/Labeled Diagram format also produced the same pattern, a positive mean gain score (11.46) but high variability among individual male subjects. Only the Labeled Diagram format produced a significantly higher mean gain score and is the only format that can be deemed appropriate for the male subjects.

It would appear that male deaf subjects comprehend information that is highly visual in nature (labeled diagram) with limited verbal information (the labeling within the diagrams). Examination of Table 13 further supports this conclusion as only the Labeled
Diagram format produced a mean gain score significantly better than the Standard Text format.

Female subjects scored higher than male subjects for all formats. Three formats produced mean gain scores that were significantly higher than chance for female subjects: the Simplified Text format (23.08), the Simplified Text/Labeled Diagram format (20.93), and the Labeled Diagram format (16.67). The Standard Text format yielded a negative mean gain score (-2.77). This format was inappropriate for the female subjects in the study and suggests that even for better readers, the Standard Text format cannot provide the hearing impaired learner with an effective mode for the comprehension of content information.

The Simplified Text format produced the highest mean gain scores for female subjects. This format appears to be the best format for enhancing the comprehension of content information for female deaf subjects, and indicates that female subjects may be more proficient with simplified text than with labeled diagrams, the reverse of the male deaf learner in the study. The Simplified Text/Labeled Diagram and Labeled Diagram formats also produced significant comprehension scores and shows that these two formats are also appropriate for female hearing impaired learners.

Table 14 presents a summary of the comparison among the formats for female subjects. The Simplified Text, Simplified Text/Labeled Diagram, and Labeled Diagram formats all produced significantly
better mean gain scores than the Standard Text, and confirm the viability of alternative instructional design formats for female hearing impaired learners.

Overall, the best instructional format for female subjects was the Simplified Text format, while for male subjects the best instructional format was the Labeled Diagram format. This result suggests that female deaf subjects are more proficient processing simplified language information and male subjects are more proficient with pictorially presented information with some verbal information for orientation. Only one format was significant for male and female subjects when the data was examined by sex: the Labeled Diagram format. Thus, if only one format could be selected to best meet the needs of the hearing impaired learner, the Labeled Diagram format is the only format that would appear to meet both learner's needs. If, however, the available resources could permit educators to select more than one format, female subjects should receive the Simplified Text format and male subjects the Labeled Diagram format. Only one format presented the key components that were beneficial to both groups, male and female. The Simplified Text/Labeled Diagram format presented the viewer with both the Simplified Text for female students and the Labeled Diagrams for male students. Thus, the Simplified Text/Labeled Diagram format would seem logically to be the best choice for instruction. It would be interesting to replicate the study without external pacing and permit
the viewer to scan all available information without the time pressure. Given the limited time, the viewer may have selected the pictorial or verbal information depending upon which the viewer could process more quickly. By comparing the Simplified Text/Labeled Diagram format under self-paced and external paced conditions, it should be possible to draw more conclusive evidence of processing differences between male and female subjects.

Table 15 summarized the rank order of format mean gain scores for all subjects. These results differed from the expected rank order listed in the Methodology section. The Simplified Text format produced the highest mean gain score. This format was predicted to be the second best format for promoting comprehension. The Simplified Text/Labeled Diagram format was predicted to be the best overall format, but results showed that it was the second most effective format. It should be noted that these results are not ranked in order of significant mean gain scores. However, the general trend in the results supports the notion that simplifying text and presenting information pictorially with verbal labeling is a valid approach for designing instructional materials for the hearing impaired learner.

The current study demonstrated that learning and comprehension can be enhanced for the hearing impaired learner by designing instructional formats which capitalize upon processing strengths and learning styles rather than penalize the learner for lack of
mastery of the English language. As a prosthetic technology, the
design principles covered in the current study will permit the
hearing impaired learner access to information and academic content
that is currently denied or limited due to the complexities of the
language. The study demonstrated that despite low reading levels
(females - 3.94; males - 2.95), demonstrated gains in comprehension
and learning are available to the hearing impaired learner. Any
textbook can be designed with a simplified text and accompanying
diagrams to permit mastery of the content information by the deaf
learner who has minimal mastery of the basic patterns of Standard
English. To continue to deny access to more advanced information
and academic content to the hearing impaired learner is inexcusable.
The condition reflects our inability to adjust to the needs of the
deaf learner rather than an inherent deficiency of the hearing
impaired learner that is insurmountable. Deaf educators must teach
towards demonstrated areas of learner strength rather than towards
areas of difficulty. In many respects, if we continue to deny the
deaf learner the opportunity to learn according to demonstrated
learning modalities, we make the same mistake as those first
educators that decided that Albert Einstein was a failure in his
first school.

The current study also suggests possible adaptation and research
for use with hearing learners who also experience difficulties
with complex linguistic processing or reading problems. The design
principles make another approach available to educators as an alternative technology to supplement current, verbal-emphasized approaches.

The design principles discussed in the study could be used to produce textbook or reading materials for the subject areas of science, social studies and math. Since schools traditionally rely on printed materials for instruction, the technology lends itself well to direct application in the design of specific materials targeted for the hearing impaired learner. The design principles could easily be adapted for use with the microcomputer and take advantage of animation and feedback capabilities. The use of simplified text and pictorial information has been demonstrated in a case study to be of benefit for daily instruction in the mainstream setting with interpreter services (Waldron, Diebold & Rose, 1985). Further study involving the application of these design principles with materials used in combination with lecture type instruction may also help to improve daily instruction.

Future studies would be of value to determine more specific information regarding the variables of Type-Token Ratio, Mean Length Utterance, percentage and type of transformations, number of words, and pictorial type. Each of the linguistic variables could be held constant in order to compare all seven types of visuals as described by Wileman (1980). Research work has documented differences in comprehension when syntactic variables
are manipulated, but pictorial design components are the least understood and utilized for research with hearing impaired subjects. Further research is needed to both verify and expand the current study regarding visual design principles.

The study did not investigate the effects of color coding to cue the viewer as to relationships between the text and diagrams. This particular design aspect could potentially lead to important design principles to more fully capitalize upon the pictorial design component. Many studies conducted with hearing subjects have suggested that color cueing is a valuable design component (Dwyer, 1972, 1978).

The mean gain score differences between the Standard Text format and Simplified Text format may reflect not only qualitative differences in terms of transformations, but also quantitative differences. The Standard Text format contained more words than the Simplified Text format (504 v. 383), and therefore subjects would have had less of an opportunity to reread the material during the 15 minute study period. Although all subjects appeared to "finish" studying the material within the specified time, no data was collected regarding actual completion times or degree of rereading.

While the mean gain score of the Simplified Text format was not significantly better than the Simplified Text/Labeled Diagram or Labeled Diagram formats, the small differences may be related
to the lack of an efficient "decoding" strategy or an excessive quantity of "cues" presented in a limited time period. Assuming that chance was not a variable, differences could reflect the inability of subjects to efficiently decode information from the diagrams simply because the format was unfamiliar to the subjects. Figure 9 is an example of the "over-under" arrangement of the Simplified Text/Labeled Diagram format used in the study. Figure 10 is an example of an alternative of the same format, with a "side-by-side" arrangement. These arrangements or compositions could be investigated in further studies to determine "decoding" differences.

Example of "over-under" composition for the Reduced Text/Diagram format

Rain is precipitation. The rain falls to the ground. The rain-water flows to a pond. The sun heats the pond water. The pond water evaporates. The pond water becomes water vapor. The water vapor cools. The water vapor condenses. The water vapor becomes a cloud. Rain falls from the cloud.

Figure 9
Example of "side-by-side" composition for Reduced Text/Diagram format

Precipitation
The rain falls to the ground.
The rain water flows to a pond.
The sun heats the pond water.
The pond water evaporates.
The pond water becomes water vapor.
The water vapor cools.
The water vapor condenses.
The water vapor becomes a cloud.
Rain falls from the cloud.

Condensation
Water vapor cools to form clouds.

Evaporation
Water evaporates by heat from sun.

Precipitation
Rain falls to ground.

Water flows to pond.

Figure 10

Lastly, the design of the relationship of the pretest, instructional format, and posttest needs further research. Such efforts would help to determine the effect of changing or maintaining the same modality (i.e., verbal or pictorial) between instruction and evaluation. What effect would a verbal text without pictures have upon a test that was either all verbal or involved the task of matching words to pictures? Although no significant relationship was found in this study between the verbal and pictorial sections of the posttest and the instructional formats, it would be interesting to determine the generalizability of information from a verbal to a pictorial mode.
In summary, the present research compared the effectiveness of pictorial and verbal text information in printed instructional formats for use by hearing impaired subjects. Four types of instructional formats were prepared which varied in the length and complexity of verbal information and in the type and number of pictorial elements. These formats were: (a) the Standard Text format which included two pictures without verbal labeling, and text which contained the complex transformations usually found in textbooks prepared for the sixth grade level; (b) the Simplified Text format which included two pictures without verbal labeling and simplified text; (c) the Simplified Text/Labeled Diagram format which included twenty labeled diagrams with simplified text; and (d) the Labeled Diagram format which included twenty labeled diagrams but no accompanying text. Each format was given to a separate group of deaf students ages 12 to 22. The instructional materials described the water cycle and the carbon dioxide-oxygen cycle. Performance was measured by gain scores calculated from pretest and posttest results. Results showed that the best instructional formats were the Simplified Text/Labeled Diagram format and the Labeled Diagram format. Both formats produced significantly higher mean gain scores when compared to the Standard Text format. The Simplified Text format also produced a higher mean gain score than the Standard Text format, but this mean gain score was not significantly different from the other
three formats. Differences also emerged between the sexes. Female subjects were most proficient with the Simplified Text followed by the Simplified Text/Labeled Diagram format and the Labeled Diagram format. Male subjects were most proficient with the Labeled Diagram format.

Since the overall results were consistent with previous research conducted with deaf subjects, the research has general implications for the design of instructional materials developed for the education of the hearing impaired learner. Differences between male and female subjects suggests that differences in processing and learning style modalities also exist for deaf learners.
APPENDIX A

INSTRUCTIONAL FORMATS
Water

Water exists in three forms: solid, liquid, or gas. Heat or cold changes the form of water. If water is heated, it may change from a liquid to a gas called vapor. If ice or snow is heated, it will change to water. If water is cooled, it may become ice or snow, which are solids. If vapor is cooled, it may become liquid water.

Cycles

A cycle is a series of steps that, sooner or later will lead back to where they started. The seasons of the year are a cycle. Spring, summer, fall, winter, and then spring again. To recycle something means to send it through a cycle again.

The Water Cycle

Water goes through a cycle. The force behind the water cycle is the sun's energy. The sun's energy causes water to change from a liquid to a gas. This process is called evaporation. Water evaporates and enters the atmosphere as a gas. When the temperature of the air falls, the gas turns back into liquid drops, known as condensation. These drops fall as rain. This process is the reverse of evaporation. If the temperature is cold enough, the drops will form a solid, snow. When the water drops or snow crystals are large enough, they will fall to the ground. This process is called precipitation. On the ground, several things may happen. The water may evaporate again. It may run off the surface in streams to lakes and the ocean, where it evaporates again. It may also sink into the ground. Here it becomes part of the ground water supply stored in the soil.
This soil water is the source of water for plants. Water is taken up by the roots of the plants and is carried up to the leaves where it is used in food making. This process of making food is known as photosynthesis. While making food, plants produce more water. This water is lost from the plants' leaves and evaporates into the atmosphere.

Water is taken in by animals, either by drinking or as part of their food. This water is eventually returned to the cycle as a waste. The same taking in and giving off of water occurs in water organisms as well as land organisms.

The water cycle can operate without the presence of living organisms. The carbon dioxide-oxygen cycle is directly related to living organisms.

The Carbon Dioxide-Oxygen Cycle

Some scientists say that the large amount of oxygen now in our air (20 percent) is due directly to the work of plants. Green plants take in carbon dioxide from the air. They use carbon dioxide with water and the sun's energy to make their food. In the process of making food, green plants release oxygen into the air.

Both plants and animals need oxygen in order to release energy from their food. During this process, oxygen is taken in and carbon dioxide is released. Many of the chemical compounds that make up living organisms contain the element carbon. This carbon is released as CO2 when the organism dies and decays.
**Water**

Water can be in three forms: liquid, solid, or gas. Most water is liquid. Ice is solid water. Snow is solid water. Vapor is water as a gas.

Water changes forms. Heat changes the form of water. Heat changes ice (solid) to water (liquid). Heat changes water (liquid) to vapor (gas).

Cold changes the form of water. Cold changes vapor (gas) to water (liquid). Cold changes water (liquid) to ice (solid). Cold changes water (liquid) to snow (solid).

**Cycles**

A cycle has many steps. The steps are in order. The steps lead away from the start. The steps go back to the start. The cycle starts again.

The seasons are a cycle. Each season is a step. Spring is the start. Spring is the first step. Summer is the second step. Fall is the third step. Winter is the fourth step. The season starts again at spring.
The Water Cycle

Water moves through a cycle. Heat moves the water cycle. The sun heats water. The water changes to vapor. Evaporation is water changing to vapor. The vapor rises into the air. The vapor becomes a cloud.

Vapor can get cold. Cold changes vapor to water drops. Condensation is vapor changing to water. Water drops fall from the clouds (rain). Precipitation is rain falling to the ground.

Vapor can be cooled to become snow flakes. Snow flakes can fall from the clouds. Precipitation is snow falling to the ground.

Precipitation is snow or rain. Some water sinks into the ground (ground water). Ground water is stored in the ground.

Some water runs off into rivers or ponds. Run off water is stored in ponds. Water can evaporate from ponds.

Plants need water. Plants get water from the ground (ground water). Water moves through the roots. Water moves to the leaves.

Plants make food (photosynthesis). Plants make food in the leaves.

Plants also make more water. Plants give off water. The water evaporates from the leaves. The water evaporates into the air.

Animals need water. Animals drink water. Animals get water from food. Animals give off water (waste water).


Dead animals give off carbon dioxide.
Water

Forms of Water

Solid  Liquid  Gas
Ice     Water     Vapor
Snow

Water can be in three forms: liquid, solid, or gas. Most water is liquid. Ice is solid water. Snow is solid water. Vapor is water as a gas.

Heat changes water

Heat

Water changes form. Heat changes the form of water. Heat changes ice (solid) to water (liquid). Heat changes water (liquid) to vapor (gas).

Cold changes water

Cold

Cold changes the form of water. Cold changes vapor (gas) to water (liquid). Cold changes water (liquid) to ice (solid). Cold changes water (liquid) to snow (solid).
Cycles

A cycle has many steps. The steps are in order. The steps lead away from
the start. The steps go back to the start. The cycle starts again.

A Cycle: The Seasons

The seasons are a cycle. Each season is a step. Spring is the start. Spring
is the first step. Summer is the second step. Fall is the third step.
Winter is the fourth step. The season starts again at spring.
The Water Cycle

Water moves through a cycle. Heat moves the water cycle.

Step 1: Evaporation. Water changes to vapor.

The sun heats water. The water changes to vapor. Evaporation is water changing to vapor. The vapor rises into the air. The vapor becomes a cloud.
Vapor can get cold. Cold changes vapor to water drops. Condensation is vapor changing to water.

Water drops fall from the clouds (rain). Precipitation is rain falling to the ground. Vapor can be cooled to become snow flakes. Snow flakes can fall from the clouds. Precipitation is snow falling to the ground. Precipitation is snow or rain.
Some water sinks into the ground (ground water). Ground water is stored in the ground.

Some water runs off into rivers or ponds. Run off water is stored in ponds. Water can evaporate from ponds.
Plants need water. Plants get water from the ground (ground water). Water moves through the roots. Water moves to the leaves.

**Photosynthesis**: Plants make food in leaves

Plants make food (photosynthesis). Plants make food in the leaves.

Plants also make more water. Plants give off water. The water evaporates from the leaves. The water evaporates into the air.
Animals need water. Animals drink water. Animals get water from food.
Animals give off water (waste water).

Dead animals give off carbon dioxide.

The Carbon Dioxide-Oxygen Cycle
Cycles

A Cycle

Start
Step 1
(back to Start)
Step 4

Step 2
Step 3

A Cycle: The Seasons

Start
Step 1: Spring
(back to Start)
Step 4: Winter

Step 2: Summer
Step 3: Fall
Labeled Diagram Format (continued)

The Water Cycle

Step 1: Evaporation. Water changes to vapor.

Step 2: Condensation. Vapor changes to water.

Heat from sun moves the water cycle.
Labeled Diagram Format (continued)

Step 3: Precipitation: Rain or snow falling


Water Cycle
Labeled Diagram Format (continued)
Water and Plants

Plants get water from ground water

Photosynthesis: Plants make food in leaves

Plants give off water

Water in Leaves

Evaporation

Vapor

Food in Leaves

Leaves

Roots

Ground Water
Labeled Diagram Format (continued)
The Carbon Dioxide-Oxygen Cycle
Labeled Diagram Format (continued)

The Carbon Dioxide–Oxygen Cycle

- Breathe Carbon Dioxide in
- Oxygen out
- Breathe Carbon Dioxide out
APPENDIX B

PRETEST AND POSTTEST
Pretest

Definitions

Match the word with the definition.

<table>
<thead>
<tr>
<th>Words</th>
<th>Definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen</td>
<td>water as a gas</td>
</tr>
<tr>
<td>Vapor</td>
<td>water changes to gas</td>
</tr>
<tr>
<td>Evaporation</td>
<td>vapor changes to water</td>
</tr>
<tr>
<td>Cycle</td>
<td>animals breathe in</td>
</tr>
<tr>
<td>Condensation</td>
<td>a series of steps</td>
</tr>
</tbody>
</table>
Multiple choice

Circle the best answer

1. Plants get water from _________.
   a. leaves c. ground water
   b. evaporation d. the sun

2. Animals breathe __________ out.
   a. cycle c. water
   b. oxygen d. carbon dioxide

3. The _______ moves the water cycle.
   a. sun's heat c. ground water
   b. rain d. carbon dioxide

4. Water that flows to a pond is _________.
   a. carbon dioxide c. a gas
   b. run off d. oxygen

5. Plants make food by _____________.
   a. photosynthesis c. breathing
   b. condensation d. drinking
### Posttest

**Definitions**

Match the word with the definition

<table>
<thead>
<tr>
<th>Words</th>
<th>Definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Oxygen</td>
<td>water as a gas</td>
</tr>
<tr>
<td>2. Run-off</td>
<td>plants make food</td>
</tr>
<tr>
<td>3. Vapor</td>
<td>water changes to gas</td>
</tr>
<tr>
<td>4. Evaporation</td>
<td>vapor changes to water</td>
</tr>
<tr>
<td>5. Cycle</td>
<td>rain or snow falls to ground</td>
</tr>
<tr>
<td>6. Carbon dioxide</td>
<td>water flows to pond or river</td>
</tr>
<tr>
<td>7. Precipitation</td>
<td>water stored in ground</td>
</tr>
<tr>
<td>8. Ground Water</td>
<td>animals breathe in</td>
</tr>
<tr>
<td>9. Condensation</td>
<td>animals breathe out</td>
</tr>
<tr>
<td>10. Photosynthesis</td>
<td>a series of steps</td>
</tr>
</tbody>
</table>
Posttest (continued)

Matching

Match the word with the picture

The Water Cycle

1. __ Run off
2. __ Condensation
3. __ Evaporation
4. __ Ground water
5. __ Precipitation
6. __ Evaporation
Matching

Match the phrase with the picture.

The Carbon Dioxide–Oxygen Cycle

1. Takes in carbon dioxide
2. Gives off oxygen
3. Gives off carbon dioxide
4. Takes in carbon dioxide
5. Takes in oxygen
6. Gives off carbon dioxide
Multiple choice

Circle the best answer

1. Plants get water from _______.
   a. leaves    c. ground water
   b. evaporation   d. the sun

2. Animals breathe ________ out.
   a. cycle    c. water
   b. oxygen   d. carbon dioxide

3. In a cycle, steps go back to the _______.
   a. ground water    c. start
   b. oxygen   d. vapor

4. The _______ moves the water cycle.
   a. sun’s heat    c. ground water
   b. rain   d. carbon dioxide

5. Plants give off ________.
   a. runoff    c. carbon dioxide
   b. precipitation   d. oxygen

6. Evaporation is water changing to ________.
   a. snow    c. precipitation
   b. ice   d. vapor
Posttest (continued)

7. Animals breathe _______ out.
   a. carbon dioxide  c. evaporation
   b. oxygen         d. ice

8. Water in the soil is ________.
   a. evaporation     c. breathe
   b. vapor          d. ground water

9. Condensation is vapor changing to ________.
   a. water           c. precipitation
   b. gas             d. oxygen

10. Dead animals give off ________.
    a. precipitation   c. cycle
    b. oxygen          d. carbon dioxide

11. Water that flows to a pond is ________.
    a. carbon dioxide  c. a gas
    b. run off        d. oxygen

12. Plants make food by ________.
    a. photosynthesis  c. breathing
    b. condensation    d. drinking

13. Vapor is water as ________.
    a. a liquid        c. a gas
    b. a solid         d. carbon dioxide
14. Rain is ________
   a. precipitation    c. solid
   b. oxygen           d. carbon dioxide

15. Animals breathe ________ in.
   a. precipitation    c. carbon dioxide
   b. oxygen           d. soil
APPENDIX C

PROTOCOL AND INSTRUCTIONS
1. **Room preparations:**
   - lights on
   - desks or tables face chalkboard
   - pretests placed face down on each desk
   - sharpened pencil placed on top of each pretest
   - directions printed on chalkboard

   1. Short test (5 minutes)
   2. Study papers (15 minutes)
   3. Test (10 minutes)

   Do your best.
   If you don't know an answer, guess.

2. **Directions:**
   - all students seated
   - all books and other materials on the floor.
   - all papers face down until I say to start

   - Directions: (Signed and Spoken. Signed English).

   My name is Tom Diebold. I am here to compare science books. I want to see which science books are best for deaf students.

   Look at this chart. (Point to chalkboard). First, you will have a short test. The test will take five (5) minutes. Second, you will study papers. I will give you the papers to study. You will study for 15 minutes. Third, you will take another test. The test will be on the information that you studied. The test will take 10 minutes.

   If you finish before the time is up, check your answers again. Do your best. If you don't know an answer, guess.
Are there any questions?

3. **Pretest:**
   - turn your papers over
   - write your name on the paper
   - you may start
   - students prompted to check their answers if finished before time limit
   - students told to stop at the end of five minutes

4. **Study formats:**
   - formats arranged in sequential order
   - exchange pretest with format with each student, format face down, pretests numbered 1 to 4 to indicate format given to student
   - turn your papers over
   - you may begin studying
   - students prompted to read again their papers if finished before time limit
   - students told to stop after 15 minutes

5. **Posttest:**
   - formats collected
   - exchange posttest for format, posttest face down
   - students reminded to recheck answers
   - turn your papers over and begin
   - students told to stop after 10 minutes
   - posttests collected
LIST OF REFERENCES


