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Processes Utilized by High School Students Reading Scientific Text

Alicia Clinger
Clemson University, aliciaclinger@gmail.com

PROCESSES UTILIZED BY HIGH SCHOOL STUDENTS READING SCIENTIFIC TEXT

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Alicia Farr Clinger
Clemson University
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Presented to:
Dr. Michelle Cook, Committee Chair
Dr. Victoria Gillis
Dr. Barbara Speziale
Dr. Penelope Vargas

ABSTRACT

In response to an increased emphasis on disciplinary literacy in the secondary science classroom, an investigation of the literacy processes utilized by high school students while reading scientific text was undertaken. A think-aloud protocol was implemented to collect data on the processes students used when not prompted while reading a magazine article and a selection from a textbook. Following the think-aloud, participants provided an oral summary that was analyzed for content and quality to assess the effectiveness of the strategies. The data showed that familiarity with text structure and prior knowledge of the content affected the processes utilized. Differences between groups (frustration, instructional, and independent levels) were noted in reading both texts. Overall, participants made references to graphics but did not rely on the content of the graphics for clarification purposes. Group differences included the amount of attention given to content vocabulary; independent level readers spent more time previewing and reviewing vocabulary. Summary scores indicated that instructional level participants used processes most effectively. Frustration level readers demonstrated the ability to utilize a variety of processes through one-time use. Findings suggested: 1) increasing instruction on interpretation of graphics; 2) providing students with varied forms of scientific text; 3) focus on teaching strategies to frustration level readers; 4) encouraging summarization activities in the classroom; and 5) using multiple forms of assessment to identify disciplinary literacy processes.

DEDICATION

This dissertation is dedicated to the memory of my grandparents, Gene and Helen McCombs, who believed I could do anything I wanted to do and were always a source of encouragement.

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TABLE OF CONTENTS

Page

TITLE PAGE i

ABSTRACT ii

DEDICATION iii

ACKNOWLEDGEMENTS iv

LIST OF TABLES viii

LIST OF FIGURES ix

CHAPTER

1. INTRODUCTION 1

    Disciplinary Literacy 1
    Background of the Problem 5
    Assessments of Learning 6
    New Directions: Disciplinary Literacy and the Standard 8
    Statement of the Problem 11
    Significance of the Study 13

2. REVIEW OF THE LITERATURE 15

    Disciplinary Literacy Research 16
    Cognitive Theories of Learning 18
    Reading Comprehension 22
    Strategies 31
    Summary 35

3. METHODS 36

    Theoretical Framework 38
    Methodology 39
    Assessments of Literacy 41
    Sampling Procedures 49
    Research Procedures 51
    Summary 56

Table of Contents (Continued)

Page

4. PRESENTATION OF FINDINGS 57

Cloze Tests 57
Questionnaire Data 58
Favorite Subject in School 64
Qualitative Analysis of Think-aloud 66
Differences in Process Use by Achievement Group 91
Oral Summary Results 96
Strategic Content Literacy Assessment (SCLA) 117
Triangulating the Data 121
Summary 123

5. DISCUSSION 124

Summary of the Study 124
Processes Utilized While Reading 125
Differences in Processes Utilized by Achievement Groups 135
Triangulation of the Data 142
Discussion 145
Limitations 147
Recommendations for Instruction 148
Implications for Future Research 152
Closing 153

APPENDICES 154

A: Participant Questionnaire 155
B: Cloze Assessment 156
C: Cloze Assessment Answer Key 157
D: Think-aloud Protocol Procedures 158
E: Oral Summaries Scoring Rubric 159
F: SCLA Reading Passage 160
G: SCLA Questions 161
H: SCLA Questions Answer Key 162
I: SCLA Scoring Rubric 163
J: Descriptions of Codes 164
K: Permission Letter from McGraw-Hill 170

REFERENCES 172

LIST OF TABLES

Table Page

1.1 Selected Common Core Standards for Grades 11-12 10

1.2 Progression of Common Core Standard Seven for Grades 6-12 11

4.1 Frustration Level Questionnaire Responses... 59

4.2 Instructional Level Level Questionnaire Responses................................. 60

4.3 Independent Level Questionnaire Responses 61

4.4 Mean Frequency of Statements Per Participant for Text Structure 68

4.5 Mean Frequency of Statements Per Participant for Prior Knowledge 74

4.6 Mean Frequency of Statements Per Participant for Reading Pattern......... 77

4.7 Mean Frequency of Statements Per Participant for Comprehension 82

4.8 Most Utilized Processes 91

4.9 Most Utilized Processes by Group for "The Brain" 92

4.10 Most Utilized Processes by Group for "Viruses" 92

4.11 Oral Summary (Content) Scores 98

4.12 Oral Summary (Content + Quality) Scores …………………..................... 98

4.13 Average Summary Scores and Comprehension Level............................. 99

4.14 Group SCLA Score Averages by Question 118

4.15 SCLA Processes and Corresponding Think-aloud Codes 122

4.16 Think-aloud Processes in Addition to SCLA Processes......................... 122

LIST OF FIGURES

Figure Page

2.1 Kreb's Cycle 27

4.1 Processes Utilized At Least Once by 50+% with Both Texts..................... 95

CHAPTER ONE

INTRODUCTION

Disciplinary Literacy

Literacy processes allow students to understand the world around them. The definition of *literacy* has evolved over the past decade as the focus of literacy has moved from a focus on generic literacy strategies and the mechanics of reading to practices more specific to a particular discipline (Conley, 2008). Literacy as defined by Thier and Daviss (2002) goes beyond the written word to include speaking and listening. Literacy has been defined by Gee (1998) as the ability to participate in and critique primary and secondary discourses. Primary discourses are those that one acquires as a by-product of their immediate environment and culture; whereas, secondary discourses are those that are specialized to a setting such as school or more specifically, an academic discipline (Gee 1998). Wallace (2004) stated that scientific literacy involves the ability to read and write scientific texts as well as the ability to be a metacognitive thinker; in other words, having the ability to understand what one does and does not know (Flavell, 1979). Gee (1998) goes on to discern the difference between degrees of literacy with the more powerful degree of literacy involving one being able to use the language of a secondary discourse for critique.

Preparing citizens who are literate in the discourses of science in order to be able to understand and critique scientific explanations is one goal of science teachers (NRC, 2012). While every student will not become a scientist, knowledge of the practices of scientists opens up a world that would otherwise be obscured by a lack of understanding of how scientists communicate information. To understand scientific reports, for example, one must have knowledge of how members of the scientific community communicate through writing in order to comprehend explanations (Lemke, 2004). The general population must have the skills to understand news and popular science magazine reports of scientific achievements (Rutherford & Ahlgren, 1990). Teaching students how to read, talk, and write like scientists helps develop such disciplinary literacy (Shanahan & Shanahan, 2008b; Moje, 2008).

Disciplinary literacy looks to experts in the field to determine what students need to learn and to be able to do in order to participate in that particular community of practice (Moje, 2008). Students also need to know how knowledge is produced and how to apply such knowledge (Moje, 2008; Shanahan & Shananhan, 2008a). McConachie (2010) notes that "disciplinary literacy involves the use of reading, reasoning, investigating, speaking, and writing required to learn and form complex content knowledge appropriate to a particular discipline" (p. 16). In their definition of *literacy*, Draper and Siebert (2010) include discipline-specific practices.

> Literacy is the ability to negotiate (e.g., read, view, listen, taste, smell, critique) and create (e.g., write, produce, sing, act, peak) texts in discipline-appropriate ways or in ways that other members of a discipline (e.g., mathematicians, historians, artists) would recognize as 'correct' or 'viable' (p. 30).

The ability to understand what one reads is critical in achieving disciplinary literacy as experts in the field communicate largely through written texts (Lemke, 2004; Tenopir & King, 2004). Tenopir and King (2004) noted that reading and writing as a form of communication occupies about half of a scientist's or engineer's work time.

Studies of expert readers who have developed a familiarity with the genre to understand how the texts are structured (Shanahan & Shanahan, 2008b; Shanahan, Shanahan, & Misischia, 2011) have influenced the creation of current science standards to provide students opportunities to develop similar understanding (Achieve Inc., 2013; NGA, 2010b). Shanahan and Shanahan (2008b) examined the processes used by scientists when reading disciplinary texts; for example, when reading, scientists were interested in visualizing the information and transforming information from text to graphic and graphic to text. Scientific text structure is multimodal in nature: information is presented in both written text and visuals (Lemke, 2004). Two processes identified as central to participating in the discipline are i) the ability to use multimodal text structure to understand the development of ideas and ii) critique of information presented with regard to evidence (Shanahan & Shanahan, 2008b; Shanahan et al., 2011).

In order to maximize learning from text, students must learn to discern the differences in the structure of narrative texts such as those found in literature or history classes as compared to those found in science classes (Shanahan & Shanahan, 2008b; Shanahan et al., 2011). Narrative texts found in history or literature classes follow a logical sequence, developing an idea throughout; while on the other hand, scientific texts rely largely on graphics to provide information that may not be contained in the written word (Lemke, 2004; Shanahan & Shanahan, 2008b; Shanahan et al., 2011). The approach that disciplinary experts take in reading the texts of their discipline is reflective of the differences in the structure of the texts of their respective disciplines; for example, disciplinary experts in history read to understand the stance of the author and to establish the author's credibility. In a scientific article, however, a scientist expects to first encounter the abstract and then expects to see methods, results, and discussion sections (Shanahan & Shanahan, 2008a; Shanahan et al., 2011). These sections of text help scientists determine what may be the most important information in the article, and they will generally reread what they find to be important in the first reading (Shanahan & Shanahan, 2008b; Shanahan et al., 2011). Furthermore, in history, visuals are viewed as supporting material that may be studied after reading written text, however, in science and math, visuals receive equal emphasis since experts know that information contained within an equation, graph, or diagram may not be completely addressed in the written text (Shanahan & Shanahan, 2008b; Shanahan et al., 2011).

From reading to problem-solving practices, disciplinary literacy in science encompasses what it means to be a scientist. Research on expert problem solving in physics delineates the skills that separate experts and novices (Larkin, McDermott, Simon, & Simon, 1980); for example, experts did not provide as much detail in their think-aloud regarding the mathematical equations utilized since they were working at a much faster pace than novices; they had automated many of the processes required to solve the problems at hand. Hmelo-Silver and Pfeffer (2004) compared the processes of experts and novices in their discussion of their knowledge of aquaria systems. Results of the study showed that novices focused more on the structure (components) of the system while experts focused more comments on the function of those components. The difference between the performance of experts and novices were attributed to experience, which has built a solid foundation of domain knowledge for the discipline (Hmelo-Silver & Pfeffer, 2004; Larkin, McDermott, Simon, & Simon, 1980).

Background of the Problem

The problem of having students who cannot understand what they read in their science textbooks has plagued high school teachers for years (Herber, 1970). With Herber's (1970) work as a guiding force, school districts and universities have sought to address the problem through content literacy instruction. The years have brought many initiatives and strategies to the forefront, all of which were to be the solution to the problem, although many of these strategies were not founded on research (Topping & McManus, 2002). Student use of general strategies such as summarizing, drawing inferences, question generation, and comprehension monitoring has been shown to improve following instruction (McKeown, Beck, & Blake, 2009). However, despite a plethora of initiatives and strategies for teachers to choose from, students are still struggling to understand what they read in their science textbooks and teachers are still at a loss as to how to really help them improve their reading skills (O'Brien, Stewart, & Moje, 1995).

Disciplinary literacy instruction departs from the recent emphasis in secondary schools on general strategy instruction (Conley, 2008; Shanahan & Shanahan, 2008b). In the recent past, trends in high school curriculum included content-area literacy strategy instruction that was intended to help students use specific strategies across the curriculum. These content literacy strategies, designed to help students break down and organize information to make comprehension more attainable (Roe, Stoodt, & Burns, 1995; Daniels & Zemelman, 2004), were often rooted in cognitive theories such as cognitive information processing theory (Simon, 1978) or schema theory (Anderson & Pearson, 1984). The more recent emphasis on disciplinary literacy instruction, on the other hand, focuses on the practices of experts in the field. Rather than teaching a strategy that students are expected to adapt to the purposes of science as with general strategy instruction, learning is scaffolded so that students are able to learn practices specific to the science discipline (Brown, Collins & Duguid, 1989; Lave & Wenger, 1991). Practices are taught in context so that students are able to make connections between content and process (Brown & Ryoo, 2008).

Assessments of Learning

The strengths and weaknesses of instructional programs over the past few decades have been measured on the international, national, and local level. Results from these assessments show that efforts to improve reading and science skills have shown little, if any, improvement in student performance.

International and National Assessments

Despite implementation of the *National Science Education Standards* (NSES) (NRC, 1996) and a focus on content literacy strategies, (Alfassi, 2004; Alvermann, 2001; Barry, 2002; Cooper, 2004; Fleming et al., 2007), the United States has not shown significant improvement on national or international assessments of learning. In 1997, the Organization for Economic Cooperation and Development (OECD) created a study of educational systems worldwide based on 15 year-old students' performance in reading, mathematics, and science. The study is termed the *Program for International Student*

Assessment (*PISA*) and is administered every three years in over 60 countries. The National Center for Education Statistics (NCES) administers *the National Assessment of Educational Progress* (*NAEP*) in the United States which assesses the performance of 4th, 8th, and 12th grade student in the areas of mathematics, reading, science, writing, the arts, civics, economics, geography, and U.S. history.

Widespread efforts to include content literacy strategy instruction have not produced the desired results; students' reading scores on *NAEP* have remained rather constant since 1971 (Rampey, Dion, & Donahue, 2009) and have declined since 2000 on *PISA* (OECD, 2011). Approximately 20% of U.S. students are unable to integrate multiple pieces of information from text and make connections within a piece of text. Although educational texts tasks comprise 25% of the 2009 *PISA* reading assessment, reading scores do not necessarily reflect how well students may be reading scientific text since scientific text passages are not specifically identified in the framework. Science *PISA* scores for U.S. students, however, show approximately 20% of students also scored at level two or below indicating these students are at-risk while less than 30% scored above level four which indicates proficiency. Level two is the minimum level at which students are able to read at in order to participate in society, whereas students who scored at level five have the ability to organize and interpret multiple pieces of text (OECD, 2011). In addition, students scoring at level five are able to read critically and develop an understanding of text that is unfamiliar in content or form (OECD, 2011). The skills needed to participate in the science discipline are closely aligned to the criteria for a level five score, indicating that many of our students have an expansive learning trajectory to travel in order to be able to participate in the discipline as an expert since so few students have scored at level five (McConachie, 2010; Draper & Siebert, 2010; Moje 2008; Shananhan & Shanahan, 2008b; Shanahan et al., 2011).

Local Assessments

The national data from *NAEP* and *PISA* are also reflected in state level end- of-course assessments. In South Carolina, during the 2013 test administration of the *Palmetto Assessment of State Standards,* approximately 60% of students demonstrated a need for additional instruction in 8th grade language arts for the reading informational texts standard and for the scientific inquiry standard for 8th grade science *(SCDOE, 2013)*. Moreover, only about 40% of students were found to have strengths on those standards on the same test (SCDOE, 2013). One explanation for this trend of students' struggling with reading in the science classroom is that strategy instruction does not meet the needs for understanding scientific text (Fisher, Grant, & Frey, 2009). Whole class instruction, in addition, often fails to meet the individual needs of students.

The focus of this study was on the practices involving the reading and interpretation of scientific text.

New Directions: Disciplinary Literacy and the Standards

In applying the aforementioned definitions of disciplinary literacy in combination with the research on the practices of experts, the *Common Core State Standards for English Language & Literacy in History/Social Studies, Science & Technical Subjects* (*CCSS*) (National Governors Association Center for Best Practices & Council of Chief State School Officers (NGA), 2010b), defined specific practices students must be able to perform by the end of high school. Shanahan and Shanahan (2008b) noted that the literacy practices of a chemist's reading focused largely on his moving between visuals and prose. Practices such as this are reflected in the CCSS (NGA,2010b); for example, by the end of high school, students in science are expected to be able to translate prose into visuals and visuals into prose, as well as to utilize multiple forms of data in order to communicate data to answer a question or solve a problem (NGA, 2010b).

The *CCSS* (NGA, 2010b) explain that focusing on the practices of scientists allows a broader view of science and expands the focus of instruction beyond mere scientific investigation. The *Next Generation Science Standards* (*NGSS*) (Achieve Inc., 2013) interpreted these practices into skills for students to develop: evaluating claims, constructing explanations, applying concepts, and communicating information. The *CCSS* (Achieve Inc., 2013) have interpreted the *College and Career Readiness Anchor Standards (*NGA, 2010a) for reading to be the guiding document for disciplinary literacy. Table 1.1 contains a list of specific skills that students should have facility with prior to completing grade 12 according to the *Reading Standards for Literacy in Science and Technical Subjects 6-12*.

Table 1.1

Selected Common Core Standards for Grades 11-12

Standard 2 Grades 11-12	Standard 5 Grades 11-12	Standard 7 Grades 11-12
Determine the central ideas or conclusions of a text: summarize complex concepts, processes or information presented in a text by paraphrasing them in simpler but still accurate form.	Analyze how the text structures information or ideas into categories or hierarchies, demonstrating understanding of the information or ideas.	Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.

These standards have been interpreted specifically for science and technical subjects and are designed to move students along the learning trajectory toward meeting the goals of the *College and Career Readiness Anchor Standards* (NGA, 2010a). The secondary grades are categorized into grade bands of 6-8, 9-10, and 11-12, in order to move students gradually toward expertise in reading scientific texts (Lave & Wenger, 1991). One example of the progression of teaching a skill is that expert readers in science view visuals to gain explanations for phenomena that they know may not be addressed in the written text, demonstrating the importance of visuals in interpreting text in science (Shanahan & Shanahan, 2008b; Shanahan et al., 2011). Standard seven addresses that need for students to interpret visual information as well as written text (see Table 1.2).

Table 1.2

Progression of Common Core Standard Seven for Grades 6-12

Grades 6-8	Grades 9-10	Grades 11-12
Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g. in a flowchart, diagram, model, graph, or table.)	Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.	Integrate and evaluate multiple sources of information presented in diverse formats and media in order to address a question or solve a problem.

The standards provide guidance in moving students along a learning trajectory toward expertise (Lave & Wenger, 1991).

Statement of the Problem

The content literacy focus of current research leans more heavily toward social studies and language arts classes. Underrepresented in the current literature are studies specific to high school science and in particular those dealing with low-achieving students' reading processes. In reviewing the literature, I was unable to find a study that specifically focused on the reading processes of students of varied achievement levels reading scientific text. The study of specific processes employed by students of all achievement levels is important; teachers are currently implementing strategy instruction intended to help improve student comprehension without substantial data to show what the varied needs of students are with respect to reading processes and strategies. In order to help their students better understand scientific text, teachers must be presented with strategies and tools in the context of science that meet their individual needs (Fisher, Grant, & Frey, 2009; McKeown et al., 2009).

The purpose of this study is to examine the literacy processes employed during the reading of scientific text by students of varied achievement levels. Research has shown how students of high achievement navigate narrative and expository text (Berkowitz, 2004; Pressley & Afflerbach, 1995). These readers are more adept at previewing text prior to reading and determining what needs to be read, and in what order, based on the reading goal (Pressley & Afflerbach, 1995). High achieving readers also utilize multiple strategies such as paraphrasing, rereading, and visualizing while reading (Berkowitz, 2004; Pressley & Afflerbach, 1995). Studies concerning students of low achievement have yielded minimal information in comparison to information about the higher achieving students; lower-achieving students are noted to possess a lesser degree of metacognitive skill which limits the information that can be gained through think-aloud studies and other self-report methods (Pressley & Afflerbach, 1995). In order to better inform classroom teachers of the specific needs of students with respect to scaffolding instruction for students reading scientific text, this study will investigate the literacy processes and cognitive skills utilized by a sample of high school students from varied achievement levels when reading scientific texts.

Grounded theory techniques were adapted for this study (Creswell, 2007; Glaser & Strauss, 1967). The following research questions guided the present study:

1. What processes and cognitive skills do students use when reading scientific text?

2. How do students of varied achievement levels differ in their reading of scientific text?

Significance of the Study

As disciplinary literacy takes center stage in science education standards, school districts and individual schools must design an approach to implementation of disciplinary literacy instruction as outlined in the *NGSS* (Achieve Inc., 2013). Paramount to the introduction of a new method of instruction is knowledge of the present state of instruction, as well as the present state of students' strategic reading of science. This study serves to provide insight into one area that will inform districts and schools as they implement disciplinary literacy instruction. Without an understanding of how well students interpret written text in the discipline as well as the processes that they use in doing so, efforts to improve disciplinary literacy would be based on faulty ground (Faggella-Luby, Graner, Deshler, & Drew, 2012).

Research on content literacy with respect to reading comprehension has grown over the past two decades. Research has involved students from elementary school through college (Callender, 2008; Daniels & Zemelman, 2004; Kozminsky & Kozminsky, 2001; Rampey et al., 2009; Roe et al., 1995; Samuelston & Braten, 2005), however, the majority of studies fall in the elementary (McKeown et al., 2009) and middle school (Berkowitz, 2004; Caldwell & Leslie, 2010; Campbell, 1999) age groups. In addition, studies in the literature report the processes and strategies utilized by high achieving students (Caldwell & Leslie, 2010; McCrudden, Magliano, & Schraw, 2010) but currently fall short in providing adequate information regarding specific processes and cognitive strategies utilized by low achieving students (Pressley & Afflerbach, 1995).

CHAPTER TWO

REVIEW OF THE LITERATURE

The *CCSS* (NGA, 2010b) emphasize disciplinary literacy practices, but moving students toward such practices first requires an understanding of their current literacy practices (Lave & Wenger, 1991). The goal of this review is to examine the body of research related to the features of scientific text and the processes underlying high school students' reading of scientific text as a means of developing disciplinary literacy. Scientific texts take multiple forms of written, visual, and verbal communication (Halliday & Martin, 1993; Lemke, 2004); however, the focus of this review will be written texts encountered by high school science students and the practices students use to make sense of what they are reading. Studies informing this review were selected through electronic database searches, a search of selected journals, and cross-referencing relevant bibliographies. Databases searched include Educational Resources Information Center, Education Research Complete, Education Full Text, PsycARTICLES, PsycINFO, PsycCRITIQUES, Social Sciences Full Text, Dissertation abstracts, and Social Sciences Citation Index; in addition, topics were also searched on Google Scholar. Keywords used in searches included the following: disciplinary literacy, content area reading, scientific literacy, reading comprehension, scientific text, content-area reading strategies, graphics, visual representations, and prior knowledge. The table of contents of the following journals were reviewed as far back as 2004 for relevant articles: *Journal of Research in Science Teaching*, *Journal of Adolescent and Adult Literacy*, *Journal of Literacy Research*, *Reading Research Quarterly*, *Science Teacher*, *Journal of College Science*

Teaching, *Journal of Educational Research*, *Journal of Educational Psychology*, *International Journal of Science Education, Science Education*, and *Journal of Science Teacher Education*. Relevant articles found in the bibliographies of studies selected for inclusion were also reviewed.

In addition to studies directly related to middle and high school students, relevant studies of upper elementary school and college freshman were reviewed as well in order to further develop an understanding of how high school students approach scientific text typically found in the science classroom.

Disciplinary Literacy Research

With the emphasis on disciplinary literacy in the *CCSS* (NGA, 2010b), increased expectations will be placed on teachers for facilitating students' understandings of scientific text, which will be a challenge for some teachers who have avoided or resisted such forms of instruction (Buckingham, 2012; Ness, 2006; O'Brien, Stewart, & Moje, 1995). Despite the small number of studies currently available in the literature (Faggella-Luby et al., 2012), several studies have established a framework for working in disciplinary literacy (Draper, 2008; Moje, 1996; Shanahan & Shanahan, 2008b).

Research in the area of disciplinary literacy has yielded information regarding how experts participate in their discipline. Draper (2008), in working with a group of teacher educators in the various disciplines determined that each discipline has different criteria for what are considered texts. In science, for example, texts may take the form of graduations on a buret or the content of a microscope slide. Also, experts in a discipline have been found to differ in their approach to texts (Shanahan & Shanahan, 2008b;

Shanahan et al., 2011). Science experts, for example, generally preview a reading selection to determine which sections are most important and give equal weight to texts and graphics since information contained in graphics may not be detailed in the written text (Shanahan & Shanahan, 2008b; Shanahan et al., 2011), while history experts may give added weight to the author and might only glance at graphics, since they often serve as an example of a topic detailed in the text (Shanahan et al., 2011).

The *CCSS* (NGA, 2010b) were designed to provide teachers guidance in preparing students to meet the demands of the discipline. Studies of experts informed the development of the NGSS (Achieve Inc., 2013). Secondary students are not expected to attain expert status, but the standards do provide guidance in moving students toward appropriate disciplinary practices. There is one primary concern for science educators as they prepare to meet the disciplinary requirements of the new standards for literacy in science (NGA, 2010b): the lack of coherence between what experts in a discipline actually do when reading and the structure of content literacy textbooks since textbooks are the primary texts for secondary students (Siebert & Draper 2008). In an analysis of content literacy textbooks, Siebert and Draper (2008) concluded that disciplinary practices such as weighing visual data equally with written text (Shanahan & Shanahan, 2008b; Shanahan et al., 2011) were either ignored or misrepresented, and texts were limited to prose.

In the few studies regarding secondary students' reading of scientific text, the shortcomings of science textbooks with regard to the development of disciplinary literacy practices are reflected. One study by Falk and Yarden (2009) provides some insight into the literacy practices of high-achieving high school students and the difficulties they have with respect to disciplinary appropriate practices. Students observed reading adapted primary literature were not sensitive to the structure of scientific text, which led to their overlooking important information as they skipped certain sections of text (Falk & Yarden, 2009). Also, in working with primary research literature, high school students reported difficulties understanding scientific terms, connecting new information to prior knowledge, and comprehending text style (Brill, Falk, & Yarden, 2004); in addition, complex descriptions of three-dimensional biological structures further complicated interpretation of illustrations (Brill et al., 2004).

Cognitive Theories of Learning

Knowledge of how students learn provides a context in which to examine the processes selected for use when reading scientific text. Cognitive theories of learning provide an understanding of how individuals process information. For the purposes of this review, I have included the following theories: meaningful learning, schema theory, theory of multimedia learning, dual coding theory, and situated cognition. Together, these theories provide a view of how students process and organize information that will provide a foundation on which to build an understanding of the processes students use when reading.

Meaningful learning theory and schema theory were selected for inclusion since these theories contribute knowledge of how new information is integrated with existing knowledge. Mayer's (2005) theory of multimedia learning and Clark and Paivio's (1991) dual coding theory were selected for inclusion because scientific text utilizes graphics to communicate information in addition to written text. The final theory included was situated cognition because it explains how one learns expert practices and moves gradually into a community of practice which supports the disciplinary literacy goals of the Common Core State Standards for Literacy (NGA, 2010b). These cognitive theories provide the basis for the selection of processes and strategies in reading comprehension.

Meaningful Learning Theory

Meaningful learning theory (Ausubel, 1960) describes learning as a process by which the learner receives new information and organizes it within the context of existing knowledge. Since the new learning will be integrated into the hierarchy of knowledge the learner possesses, activation of prior knowledge is a prerequisite for learning. New knowledge can be a superordinate idea under which prior knowledge is subsumed, or it can be an additional example of a familiar concept and can be subsumed under existing knowledge. The two types of subsumption are derivative and correlative. Derivative subsumption involves the extension of existing knowledge; in other words, the information may serve as an additional example of a concept and has not altered the learner's existing knowledge. If new knowledge does involve information that does not match an existing concept, it must be modified through a process known as correlative subsumption. Combinatorial learning involves deriving meaning from existing knowledge that is on the same level of the knowledge hierarchy but represents a different concept much like an analogy. Instructional considerations based on this theory include the use of advanced organizers, which serve to help learners organize the information by helping them activate prior knowledge (Ausubel, 1960).

Schema Theory

Schema theory (Anderson & Pearson, 1984) follows a similar line of thinking. Schemata are mental representations that can be modified as new learning is introduced. As new knowledge is encountered, existing schema may be modified by one of three processes: accretion, tuning or restructuring. Accretion occurs when new learning is similar to knowledge in an existing schema: in this instance, the new learning may be considered as an additional example but the schema is not otherwise altered as with Ausubel's (1960) deriviative subsumption. In line with Ausubel's (1960) correlative subsumption, schema theory's notion of the tuning of schemata occurs when an existing schema needs to be expanded to accommodate a new facet of knowledge. Restructuring, which is similar to superordinate learning or combinatorial learning in meaningful learning theory (Ausubel, 1960), involves the creation of a new schema when new knowledge is very different from existing schema.

Theory of Multimedia Learning

Mayer's (2005) theory of multimedia learning focuses on how individuals learn from both text and graphics. Several cognitive processes are considered key in learning from multimedia: selecting relevant words and images from text or illustrations, and creating oral presentations or pictorial representations from words and images respectively (Mayer, 2005). This processing of verbal and pictorial presentations occurs through a process of dual coding (Clark & Paivio, 1991; Paas, Renkl, & Sweller, 2004).

Dual Coding Theory

Dual coding theory states that information is processed through auditory and visual channels. Mayer's (2005) theory of multimedia learning focuses on how individuals learn from both text and graphics through a process of dual coding (Clark & Paivio, 1991). According to this theory, information is processed through auditory and visual channels that are independent of one another, and the storage of information from the two channels is separate which provides two locations from which the information can be retrieved (Clark & Paivio, 1991). Instructional implications from multimedia learning (Mayer, 2005) and dual coding theory (Clark & Paivio, 1991) support providing learners with both visual and verbal stimuli for a concept so that chances of retrieval of that information are greater.

Meaningful learning, schema theory, and multimedia learning theory support the idea that there is a limit to the amount of information that can be processed at one time (Ausubel, 1960; Clark & Paivio, 1991; Mayer, 2005). This notion of a limit on how much information can be handled in working memory is reflected in Cognitive Load Theory (Paas et al., 2004).

Situated Cognition

Situated cognition assumes learning is rooted in participation in an activity (Brown, Collins, & Duguid, 1989). Learners benefit from authentic activities that enculturate them into the community of practice by allowing them to participate in activities such as speaking, reading and writing. Such authentic activities allow learners to build expertise in the community of practice (Lave & Wenger, 1991). This theory has been translated into the instructional practice termed cognitive apprenticeship (Brown, Collins & Newman, 1989) or situated learning (Lave & Wenger, 1991). Cognitive apprenticeship or situated learning involves providing novices the opportunity to first observe and then to gradually increase participation in the practices of a community until they have gained full membership into that community.

Reading Comprehension

Research on comprehension of scientific text has shown that several factors such as text structure, prior knowledge, organization of knowledge, interactive knowledge, and comprehension ability influence a reader's comprehension (Cromley, Snyder-Hogan, & Luciw-Dubas, 2010; McCrudden et al., 2010; Ridgeway, 1994; Samuelsten and Braten, 2005). The knowledge domain from which text is drawn has been shown to influence the degree to which organization of knowledge and interactive knowledge are effective in aiding comprehension (Ridgeway, 1994). For the purposes of this review, factors reviewed were limited to text structure and prior knowledge, since students' degree of familiarity with text structure and level of prior knowledge are factors that can be easily assessed by a classroom teacher.

The following sections of this review focus on scientific text structure, prior knowledge, and strategies as each contributes to comprehension of text and the development of disciplinary literacy.

Scientific Text Structure

Scientific text is more abstract than narrative texts, and the structure of the text may provide challenges to readers who are proficient in reading narrative texts (Fang, 2005; Halliday & Martin, 1993). Scientific text is characterized by nominalization of verbs, unfamiliar technical terms, and complex sentence structure (Halliday & Martin, 1993). Scientific text involves verbal, mathematical, visual, and technical concepts and unlike narrative text, scientific text may include important information in graphics without providing further explanation (Halliday & Martin, 1993; Lemke, 2004).

In many cases, the divide between a student's out-of-school culture and literacy practices and the literacy practices of a discipline are so great that students do not have the skill to access information presented in scientific text (Conley & Wise, 2011; Moje, 1996). The abstract nature of scientific text also contrasts with many texts encountered by students in their out-of-school reading such as graphic novels or mystery novels that are rich in description and detail (Moje, 1996). Efforts to build on a student's out-of-school literacy practices in order to gain an understanding of disciplinary literacy practices allow students access to new knowledge (Conley & Wise, 2011; Moje, 1996).

Text structure deserves a place in disciplinary literacy instruction since understanding the structure makes the meaning of the text available to students (Meyer, Brandt, & Bluth, 1980). Unfortunately, a very small percentage of instruction in the science classrooms focuses on understanding text structure (Ness, 2006). Following are reviews of the roles that vocabulary, sentence structure, and graphics play in increasing the difficulty level of scientific text.

Vocabulary. Vocabulary in scientific text is most often complex and abstract (Baker, 2004). Textbooks contain a large number of unfamiliar terms that prove difficult for many students to understand even with the glossary, especially students who struggle with reading (Nair, 2007).

Nominalized vocabulary. Scientific vocabulary relies heavily on the nominalization of verbs and adverbs (Halliday & Martin, 1993). Nominalization is a process whereby verbs and adjectives are turned into nouns (Halliday & Martin, 1993); for example, in biology verbs such as *classify* become nouns such as *classification*. Such nominalizations make the vocabulary more abstract and difficult to read because they often conceal the action of a sentence (Fang & Schleppegrell, 2010; Halliday & Martin, 1993). Consider the role of the verb *transcribe* in the first sentence as compared to its use as a noun in the second sentence below:

The RNA code is **transcribed** in the first stage of protein synthesis.

RNA **transcription** is the first stage of protein synthesis.

In the first sentence above, the action of the sentence is clearly *is transcribed*, but in the second sentence the action is concealed within the nominalization *transcription*.

Unfamiliar/technical vocabulary. The perceived difficulty of scientific text structure affects student motivation to read (Mikk & Kukemelk, 2010). Unfamiliar and often technical terms decrease the motivation of students reading biology and can affect students' perceived abilities, utility value, and attainment value (Mikk & Kukemelk, 2010). Biology texts, as opposed to physics or chemistry texts, are perceived to be more difficult and contribute to greater differences in motivation in high and low achievers (DeBacker & Nelson, 2000). The following sentences from a chemistry (Wilbraham, Staley, Matta, & Waterman, 2008) and a biology (Biggs et al., 2008) text, for example, demonstrate such features with respect to unfamiliar and technical vocabulary:

> Carbohydrates are monomers and polymers of aldehydes and ketones that have numerous hydroxyl groups attached; they are made up of carbon hydrogen, and oxygen (Wilbraham et al., 2008, p. 696).

> ATP is produced in conjunction with electron transport by the process of chemiosmosis - the mechanism by which ATP is produced as a result of the flow of electrons down a concentration gradient (Biggs et al., 2008, p. 224).

The first passage above, taken from a chemistry text, contains nine unfamiliar specialized terms in one sentence. To understand the concept of a carbohydrate, the reader must be familiar with the following terms*: monomers, polymers, aldehydes, ketones, hydroxyl groups, carbon, hydrogen,* and *oxygen*. The second passage, one from a biology text, contains five specialized terms (*ATP, electron transport, chemiosmosis, electrons,* and *concentration gradient*). Unlike the terms in the chemistry passage, the terms in the biology passage represent additional processes that carry with them their own specialized terms to be understood, making this passage more complex for students to interpret (DeBacker & Nelson, 2000; Halliday & Martin, 1993; Mikk & Kukemelk, 2010) .

Sentence structure. Beyond the aforementioned use of nominalized vocabulary and technical terms in scientific text, the organization of sentences in scientific text differs from many of the texts encountered by students. Fang and Schleppegrell (2010) describe a process whereby sentence structure can be analyzed, thus allowing a better understanding of sentence organization. In analyzing text through functional language analysis, the processes represented in clauses and the sources of action are identified (Fang & Schleppegrell, 2010). Fang and Wang (2011) have presented the rheme/theme model for applying functional language analysis that teachers and students can use. Using the rheme/theme analysis which identifies the point of departure to a new concept within a sentence, students can observe that a scientific text written by an expert will take each departure or rheme and follow it into the next sentence as the theme, this process creates a more cohesive text than one that may be written by a novice that may seem to be more a collection of facts that are not interconnected. For example, consider the following brief passage on recombinant DNA technology from a popular biology textbook:

> The first practical application of **recombinant DNA technology** was to insert the gene for making <u>*insulin*</u> into bacteria. Most people naturally make **insulin**, a polypeptide that controls levels of blood sugar, but insufficient insulin production results in <u>*diabetes*</u>. The symptoms of **diabetes** can be controlled by <u>*insulin injections*</u> (Biggs et al., 2008, p.784).

The bold words represent the theme of a sentence and the italicized underlined terms represent rheme which becomes the theme in the following sentence. This zig-zagging pattern is commonly found in scientific text, allowing new information to be added while maintaining a discursive flow (Fang & Schleppegrell, 2010; Fang & Wang, 2011).

Graphics. Text structure in terms of sentence structure and dense vocabulary are not the only barriers students face in understanding scientific text. Graphics in scientific text often pose a larger challenge for readers than written text (Halliday & Martin, 1993). Visuals in textbooks pose a unique problem in that they often lack explanations or the explanations may lead students to form misconceptions (Pinto & Amettler, 2002). The diagram in Figure 2.1 of the Kreb's cycle from a popular biology book (Biggs et al., 2008) represents multiple steps in a process although the caption simply alludes to a summary of the process. Many students have difficulty following the steps in such a diagram without explicit explanations of each step.

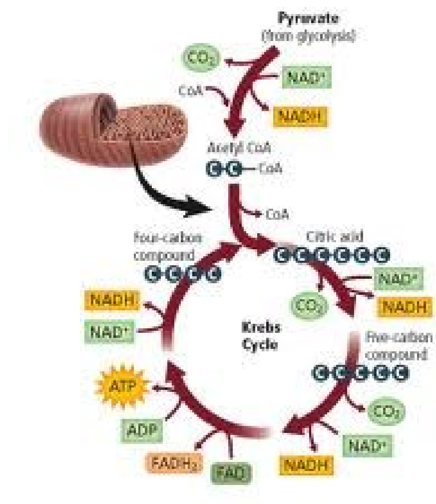


Figure 2.1. Pyruvate is broken down into carbon dioxide during the Krebs cycle inside the mitochondria of the cell. Reprinted *from Biology: The Dynamics of Life* (p. 230) by A. Biggs, W. C. Hagins, W.G. Holliday, C.L. Kapicka, L. Lundgren, A.H. MacKenzie, R.D. Rogers, M.B. Sewer, & D. Zike, (Eds.) (2008), New York, NY: McGraw-Hill. Copyright 2008. Reproduced with permission of the McGraw-Hill Companies.

Processing of visual text requires the reader to integrate the presented information with prior domain-specific knowledge and to make connections to the written text (Clark & Paivio, 1991; Mayer 2005). Poorly designed visuals may increase cognitive load which interferes with processing (Kirschner, 2002). Visuals that are clear to read, either through data presentation or brief explanations, can reduce cognitive load and elaborate on the written text, thus improving processing and learning (McTigue & Flowers, 2011; Cook, 2008; Pinto & Ametller, 2002). Reducing cognitive load does not, however, translate into reducing learning tasks (Paas et al., 2004). Graphics found in science texts possess unique features that affect the manner in which students interact with them and how well they will be able to integrate this information with existing prior knowledge (Anderson & Pearson, 1984; Ausubel, 1960). The type of image first captures the attention of students. Many textbooks are filled with realistic images or summarized data as opposed to authentic graphs and symbolic diagrams (Pinto & Amettler, 2002; Dimopoulos, Koulaidis, & Sklaveniti, 2003). Students' interpretations of realistic images do not often address the content it is meant to support since their interpretations reflect the real world and are often literal (Pinto & Ametller, 2002). A photograph of an eagle and a beetle in flight, for example, is intended to demonstrate analogous structures (Biggs et al., 2008, p. 435, fig 15.7) but students may focus less on the similar function of the wings than on the general differences between eagles and beetles.

The amount of accompanying explanation a graphic provides also affects how well students can interpret its meaning. As reflected in student ordering of diagrams representing the water cycle based on the criteria of utility, even a second grade student recognizes a useful graphic as noted by the comment, "It doesn't have as much stuff to explain it," (McTigue & Flowers, 2011, p. 582). While arrows and other tools are used to direct the readers' attention when reading a graphic, the overuse of such tools is often frustrating and inhibits the ability to read the graphic (McTigue & Flowers, 2011).

The way in which students approach graphics in text are reflective of the practices they have experienced in classrooms. In one study of almost 400 K-5 teachers, fewer than 10% reported modeling interpretation of graphics for their students. Instead, most reported that they simply refer to or point to the visuals (Coleman, McTigue, & Smolkin, 2011). These teachers also reported that the types of graphics utilized in their classrooms most often are flow diagrams, picture glossaries, cross-section diagrams, web diagrams, and cut-away diagrams. With students not taught how to interpret these graphics, it is no wonder that they often view them as an afterthought (Pinto & Ametller, 2002; McTigue & Flowers, 2011). This trend goes against the disciplinary practices of scientists who rely heavily on information contained in graphics (Shanahan & Shananhan, 2008b; Shanahan et al., 2011).

Prior Knowledge

Prior knowledge also plays an important role in the ability to interpret graphics and text effectively. Students activate prior knowledge and integrate new information into an existing schema (Cromley et al., 2010). Students with a higher degree of prior knowledge were found to be able to discern small details in a graphic better than students with a lesser degree of knowledge (Cook, 2006; Cook, Wiebe, & Carter, 2008). Working with honors and advanced placement biology students, Cook and colleagues (2008) found that students with higher levels of knowledge spent more time trying to determine why a visual did not match their expectations for the phenomena being studied while students with lower levels of knowledge assumed their interpretation was correct and moved on. The higher knowledge students realized that they were reaching the same conclusion as the lower knowledge students: this conclusion seemed incorrect, so they probed further to seek an answer. When students realized they had overlooked a colored arrow in the visual, their questions were answered and then the visual made sense because of their prior knowledge. Hannus and Hyona (1999) found a similar trend among Finnish fourth grade students interpreting images in their elementary biology text.

Emphasis is often placed on the role of activating prior knowledge in order to facilitate comprehension of text and graphics; however, it is worthy to note that many novice learners have imperfect or disorganized prior knowledge as opposed to high quality or organized prior knowledge (Callender, 2008). Callender (2008), in working with college undergraduates, examined the effect of highly organized and poorly organized prior knowledge on comprehension of unfamiliar material and they found that even imperfect or disorganized prior knowledge improved comprehension better than no prior knowledge. Prior knowledge has also been found to mediate poor decoding skills in measures of comprehension (Samuelstuen & Braten, 2005). Students in vocational track classes and learning-disabled students perform poorly in comparison to higher level classes on measures of reading comprehension involving general literacy processes due to having an incomplete understanding of the material (Kozminsky & Kozminsky, 2001).

Students with higher levels of prior knowledge are able use text clues to make more global inferences than students with lower levels of prior knowledge because they have an existing schema into which the new information can be processed (Janssen, Brasksma, & Rijlaarrsdam, 2006; Kendeou & van den Broek, 2007; Wieland, 2008). Students who are able to effectively use prior knowledge and text clues to generate inferences have had varied experiences in using strategies (Truong, 2002). The degree of prior knowledge held by college undergraduates when reading physics text affected their memory of the text as well as the cognitive processes utilized especially when the reader held misconceptions prior to reading the text (Kendeou & van den Broek, 2007). Helping students make connections to prior knowledge can facilitate understanding of scientific text. In the recent past, the focus on strategy instruction sought to address needs such as activating prior knowledge and accessing text although there is little evidence that these strategies have greatly improved comprehension (OECD, 2011; Rampey et al., 2009).

Strategies

As the move toward disciplinary literacy instruction moves to the forefront in science education with the implementation of the *CCSS* (NGA, 2010b), it is important to understand how students have been instructed in the recent past with regard to literacy in science. The past two decades have seen a focus on cognitive strategy instruction as a means to increase content literacy. As teachers strive to implement the new literacy standards in science (NGA, 2010b), they will need to build on the foundation that students have developed which includes cognitive strategies they have learned to use. This portion of the review will focus on a discussion of research on cognitive and content literacy strategies students have been taught to use with expository text, focusing on scientific texts in particular.

Cognitive vs. Content Literacy Strategies

Cognitive strategies are "the ways that learners guide their own learning, thinking, acting, and feeling," (Driscoll, p. 362). Some cognitive strategies employed by students while reading scientific text include making inferences (Munoz, Magliano, & Sheridan, 2006; Kendeou & van den Broek, 2007; McKeown et al., 2009; Ritchey, 2011), summarizing, clarifying, and self-questioning (Kozminsky & Kozminsky, 2001;

McKeown et al., 2009). When cognitive strategies are taught to students for the purpose of learning in the content area, they are often referred to as content area or content literacy strategies (Fisher & Frey, 2008). In teaching content literacy strategies, teachers model the strategy by thinking aloud to demonstrate the cognitive processes involved. In addition, through appropriate scaffolding, students will eventually make use of the strategies without conscious effort (Fisher & Frey, 2008).

Effects of Strategy Instruction on High vs. Low Achieving Readers

High and low-achieving readers are noted to differ in their abilities to utilize content literacy strategies. Kozminsky and Kozminsky (2001), in working with Israeli high school students of different achievement groups reading a variety of short texts, examined their knowledge of strategies on reading comprehension. Summary, clarification, self-questioning, and prediction were the strategies examined. Significant differences between academic groups were noted and results showed that clarification strategies were moderately related to comprehension in all academic groups. The lowest academic group's comprehension scores were affected by effective use of self-questioning strategies. The average academic group's comprehension was also correlated to summarization and prediction strategies. The highest academic group's comprehension scores reflected effective use of all four strategies (Kozminsky & Kozminsky, 2001). Building on Kozminsky and Kozminsky's (2001) work, Cromley and Azevedo (2011) studied strategy use, vocabulary, word reading fluency, and inference measures as predictors of comprehension in undergraduates and ninth grade high school students. Vocabulary was noted to influence comprehension more than strategy usage with the high school students; however, they went on to explain that with high school students in particular, strategy use is correlated with the other predictors of comprehension as well. Cromley and Azevedo (2011) acknowledged that vocabulary and inference measures may have been results of effective strategy use. In considering the implications of their study, they also cautioned that strategy instruction's effectiveness with students may depend on their students' knowledge of other predictors of comprehension such as vocabulary.

Content literacy strategies have been found to be most helpful in improving comprehension in higher-achieving students (Caldwell & Leslie, 2010; Israel, 2008; McCrudden et al., 2010). Students who are considered good readers generally are able to paraphrase while reading more than less able readers (Caldwell & Leslie, 2010). The ability to paraphrase text while reading has been related to greater verbal ability; thus, contributing to greater comprehension and recall (McCrudden et al., 2010). Good readers with higher-order thinking skills are better able to employ shifting strategies that allow them to comprehend what they are reading. Shifting strategies allow the reader to form liberal interpretations of text as opposed to limited and literal interpretations of the text which are characteristic of less able readers (Israel, 2008). Low-achieving readers have shown some improvement in comprehension with instruction in summarization, questioning, prediction, and clarification (Kozminsky & Kozminsky, 2001; Palinscar & Brown, 1984). Although strategy instruction has been shown to be beneficial to some degree for low-achieving students, keeping the main focus on content has been found to yield better results (McKeown et al., 2009).

Strategy Instruction for Disciplinary Literacy

According to Alexander, Kulikowich, and Jetton (1994),

> if we are to improve the state of learning for our school-aged populations, then we need to situate these developing minds in learning environments in which teachers are knowledgeable about the domain which they are instructing and sensitive to the domain-specific and general strategies required when students navigate within that environment,(p.213).

Recommendations for implementing strategy instruction in order to foster disciplinary literacy include pairing content teachers with literacy specialists (Jetton & Shanahan, 2012). The reason behind such recommendations is that content teachers know which strategies and skills students will need for the discipline and literacy specialists are knowledgeable in how to facilitate the skill acquisition. Cognitive strategies such as Reciprocal Teaching (Palinscar & Brown, 1984) are useful in scaffolding students to independent use of disciplinary strategies

Jetton and Shanahan (2012) categorize strategies as general, adaptable and specific. They note that these strategies may be most effective with helping readers attend to the text as opposed to increasing comprehension of a text. Adaptable strategies such as comparison charts can be used in a variety of disciplines to increase understanding of the text, however, without specific instruction in how to use these adaptable strategies in a given discipline, students are unlikely to use them effectively (Jetton & Shanahan, 2012). Strategies specific to a discipline such as translating visual text in science are unique to the discipline and must be taught in context. Jetton and Shanahan (2012) recommend teaching students how to use the general and adaptable strategies in their discipline appropriately and to teach discipline specific strategies.

Summary

The new literacy standards for science (NGA, 2010b) emphasize disciplinary literacy practices. As educators work to refocus their efforts in the classroom in order to implement these new standards, they need an understanding of the foundation students have for reading and comprehending scientific texts is needed.

Comprehension of scientific text is largely dependent upon a student's facility with scientific text structure. Scientific texts are unique in that they include dense, technical vocabulary as well as sentence structures full of nominal groups, as well ascomplex visuals which present a challenge for low-achieving readers in particular (Fang, 2005; Halliday & Martin, 1993; Lemke, 2004). Students need to be provided with opportunities to work with varied texts in order to gain expertise in reading scientific text (Conley & Wise, 2011; Jetton & Shanahan, 2012; Moje, 2008). Content literacy strategy instruction supports the goals of disciplinary literacy instruction in that it provides a foundation on which to build expertise. Teachers must understand, however, if a particular strategy is appropriate for the content (Moje, Young, Readance, & Moore, 2000) and whether or not it fosters disciplinary literacy (Moje, 2008).

Through a review of the literature on scientific text, cognitive learning strategies, strategy instruction, and prior knowledge, a gap emerges with regard to how high school students use these elements of learning when reading scientific text. In other words, there is little information indicating what processes students are actually using when they independently read scientific text.

CHAPTER THREE

METHODS

The purpose stated for this study was to understand what processes high school students used while reading scientific text and how different achievement groups differ in processes they used since this information is not well represented in the current literature. Such understanding could only be gained from the data. I entered this study acknowledging my own assumptions regarding students' processes while reading scientific texts. My assumptions were as follows:

1. Students of varied achievement levels use different processes and cognitive skills when reading scientific text. Studies have shown that higher achieving readers utilize more varied cognitive strategies when reading text as compared to lower achieving readers (Janssen, et al., 2006; Kozminsky & Kozminsky, 2001; Pressley & Afflerbach, 1995).
2. Prior knowledge of content and scientific text structure facilitates comprehension of scientific text. Students more knowledgeable in science are better able to approach text and comprehend material than those possessing less prior knowledge (Cromley et al., 2010; Kendeou and van den Broek, 2007; Kozminsky & Kozminsky, 2001; Li, 1999; Samuelsteun & Braten, 2005).
3. Building from the previous assumption that prior knowledge of content facilitates comprehension knowledge (Cromley et al., 2010; Kendeou and van den Broek, 2007; Kozminsky & Kozminsky, 2001; Li, 1999; Samuelsteun & Braten, 2005), I assume that students who enjoy reading or those who consider

themselves to be good readers in other subject areas will struggle as much as students who are avid or self-described good readers when prior knowledge of the content is low.

4. Students' comprehension of scientific text is low when they are left to their own devices when prior knowledge of content is low or absent. In keeping with the research on the effects of knowledge of text structure and prior knowledge of content in facilitating students' abilities to comprehend text (Cromley et al., 2010; Kendeou and van den Broek, 2007; Kozminsky & Kozminsky, 2001; Li, 1999; Samuelsteun & Braten, 2005), it is assumed that when the text and content are unfamiliar, comprehension will be low if no support is offered through prompting or other scaffolding measures.

Bracketing has been described as a process by which a researcher suspends assumptions in order to objectively observe and describe phenomenon (Gearing, 2004). While bracketing is credited to the work of Husserl (2012), many of his students and peers rejected the concept on the basis that humans do not have the capacity to ignore preconceptions. Instead, opponents to the concept of bracketing valued contextual meaning and interpretation as a means of describing a phenomenon (Gearing, 2004). This study examined the reading processes of high school students while reading scientific text in the context of the school setting. In order to get an accurate portrayal of the processes students use while reading scientific text, the information collected needed to be free from interpretation so that the processes observed could speak for themselves. For this reason, every effort was made to set aside my assumptions and view the data in an objective manner. With these assumptions set aside, methods were selected to allow the processes that students were using to emerge through qualitative coding techniques rather than utilizing an *a priori* coding scheme. Keeping in mind the notion that humans are not capable of setting aside assumptions (Gearing, 2004), it should be noted, however, that despite efforts to ignore assumptions, the assumptions held may have influenced my interpretation of the data.

Theoretical Framework

My ontological view is that reality is constructed by individuals based on their experiences. In keeping with the ontological view that there are multiple interpretations of reality, it is my epistemological belief that the way which individuals understand the world that exists around them is socially constructed as they interact with their culture or community. Individuals create meaning for things based on their interactions within their culture or community which can lead to varied interpretations of phenomena within a population as opposed to the assumption that there is only one truth (Crotty, 1998; Guba & Lincoln, 1994). Although I accept that there may be varied interpretations of phenomena, which are aligned with a relativist position, I reject the idea that all interpretations of reality are of equal value (Schwandt, 1994). Within a culture or community, normative criteria exist for judging the value in various interpretations of phenomena and therefore what counts as knowledge (Gergen, 1985; Hammersley, 2009). This interaction over time leads to revised interpretations that are more compatible with that of more experienced members of the culture or community (Gergen, 1985; Guba &

Lincoln, 1994). Taking into consideration the above mentioned assumptions, I have positioned myself as a symbolic interactionist (Blumer, 1969).

The elements of symbolic interactionism (Blumer, 1969) reflect my belief that students learn through interactions with peers, teachers, texts, and the environment. As students gain more experiences, their views and meanings assigned to phenomena are refined toward those of experts with whom they increasingly interact. This belief is reflected in the situated learning theory (Lave & Wenger, 1991) which formed the basis for my inquiry in this study; I wanted to know where students were on the learning trajectory from apprentice to expertise with regard to reading scientific text.

My theoretical perspective provided the foundation on which grounded theory methods were selected for interpreting data on how students read scientific text. Participants constructed meaning based on their experiences and I, as researcher, interpreted their processes based on my experiences.

Methodology

Information regarding the processes students use when reading scientific text rests in the observable processes and reported thoughts of participants as they read scientific text (Ericsson & Simon, 1993; Pressley & Afflerbach, 1995). In addition, a description of the processes used by different achievement groups when reading scientific text was developed through comparison of the data collected on each participant (Glaser & Strauss, 1967). The purpose of this study was to understand the processes high school students use while reading scientific text and to understand the differences between achievement groups; therefore, methods were desired that would capture their thoughts with the least amount of interference from the researcher or instrument. Although the present study is not a grounded theory study, grounded theory methods were selected for this study, since this approach allowed the processes students use when reading scientific text to emerge (Glaser & Strauss, 1967).

As comparisons were to be made between achievement groups, an instrument was needed to separate the participants into three groups. Instruments for data collection in this study were selected from those that are easily designed by teachers for use in the classroom. The instrument selected to group participants was the cloze assessment (Taylor, 1956), as it not only assesses reading achievement with regard to a particular text but it can be easily designed by the classroom teacher.

In order to understand how high school students construct understanding while reading scientific text, methods were sought that would allow the information to be collected from participants without interference from the researcher. A protocol (Ericsson & Simon, 1993; Pressley & Afflerbach, 1995) was selected to collect data regarding literacy processes utilized as participants read. Two genres of text were selected for use with the think-aloud protocol in order to examine whether prior knowledge of text structure (Kendeou & van den Broek, 2007) also played a role in the processes utilized and comprehension. Using constant comparative methods whereby codes describing literacy processes evident in the think-aloud data were compared within and across participants allowed categories of process utilization to emerge (Charmaz, 2006; Glaser & Strauss, 1967; Strauss & Corbin, 1990).

Triangulation of the data was accomplished through use of a Strategic Content Literacy Assessment (SCLA) (Alvermann, et al., 2013), which was based on Brownlie, Feniak, and Schnellert's (2006) Standard Reading Assessment.

Assessments of Literacy

Methods for eliciting information regarding reading level, cognitive processes, and disciplinary-appropriate literacy strategies are readily available to classroom teachers. The cloze (Taylor, 1953) and SCLA (Alvermann et al., 2013) are assessments that are easy to administer and they also allow insight into students' prior knowledge and comprehension of a particular text. A more detailed picture of how students read text can be ascertained through use of a think-aloud protocol. These instruments were included in this study and are examined in the following pages.

Cloze Tests

Cloze tests were created by Taylor (1953) as a way to assess the readability of text by leaving out every *nth* word for the reader to fill in with appropriate terms. A few years after the initial development, the cloze test began to be used as an assessment of a reader's comprehension (Taylor, 1956).

Research on the use of cloze procedures with secondary school students focused mostly on middle school students (Helfeldt, Henk, & Fotos, 1986; O'Toole & King, 2011). Cloze procedures are used to assess students' instructional reading levels and are relatively easy to produce and administer to large groups (Brown-Chidsey, Davis, & Maya, 2003). Debate over the degree of reading skill that can be ascertained by the results of a cloze procedure has ranged from criticism of the absolute scoring of responses rather than acceptance of synonyms (Greene, 2001; O'Toole & King, 2011) to the degree of cueing provided (Helfeldt et al., 1986). In working with college students in an introductory economics course, Greene (2001) used a discourse cloze procedure to better assess the ability of readers to construct the text based on inferences generated within the text.

Research has shown that performance on cloze tests is comparable to performance on other measures of reading achievement (Williams, Ari, & Santamaria, 2011). The traditional format of the cloze test involves selecting a passage of approximately 250 words in length and deleting every *n*th word, where *n* ranges from 5 to 7, depending on the age of the reader for all but the first and last sentences (Helfeldt et al., 1986). The text selected for use as a cloze assessment for this study was selected from the textbook currently used by the school the participants attend. This text was also the text from which one of the think-aloud passages was selected, making the cloze assessment a more valid predictor of cognitive skill with that particular text. The topic of cell reproduction was selected because students would have some prior knowledge of the topic from study in seventh grade science; the topic of cells was addressed in seventh grade science as well as biology. This passage may have activated prior knowledge for some participants, which could have influenced their recall of prior knowledge on the think-aloud completed in the next phase of the study. Using the cloze as a measure of prior knowledge, Ridgeway (1994) showed through multiple regression analysis that the interactive use of prior knowledge and comprehension strategies affects the degree of comprehension of some scientific text. Beginning with the second sentence, the 181-word passage included

31 deletions that occurred every fifth word and stopped before the last sentence of the passage (Helfeldt et al., 1986; Taylor, 1953). The deletions represented eight content vocabulary terms, three verbs, one adverb, one adjective, three prepositions, one article, and one conjunction. One content vocabulary term was repeated twice and one verb was repeated once.

In order to provide a measure of comparison between the cloze assessment and the Common Core Standards for Literacy in Science and Technical Subjects (NGA 2010b), the level of complexity of the cloze passage was calculated. The Lexile score, a measure of text complexity based on semantic and syntactic elements of a text, is referenced in the (NGA, Common Core Standards (NGA, 2010b). It provides guidance for educators with respect to the complexity level of texts with which students should be familiar at a grade level. The Lexile level of the text from which the cloze assessment for this study was designed was found to be 980. The grade band associated with a Lexile of 980 on the revised scale was grades 6-8; however, at the time the textbook was written, this Lexile level was associated with grades 9-10 (NGA, 2010a).

The traditional format of the cloze test was selected for use in this study as the participants had some prior knowledge related to the topic assessed; therefore, it was expected that participants had knowledge of the scientific terms needed to complete the cloze. The sample of volunteers was assessed using a cloze assessment in order to group students based on reading achievement. In order to group students, those participants whose scores on the assessment fell below 40% were placed in the frustration level reader group (Alvermann et al., 2013; Bormuth, 1968). Participants who scored between 40%

and 60% were placed in the instructional level reader group and participants who scored above 60% were place in the independent level reader group (Alvermann et al., 2013; Bormuth, 1968).

Think-Aloud Studies

The think-aloud method elicits on-line, or during reading processes, from readers. Think-aloud methods have been successful in yielding data that have led to improved tests, surveys, and written discourse (Camburn, Correnti, & Taylor, 2000; Johnstone, Bottsford-Miller, & Thompson, 2006; Schellings & Broekkamp, 2011).

The process of having students share thoughts as a means of understanding how they learn dates back centuries continuing well into the mid-20th century as introspective studies (Ericsson & Simon, 1993; Pressley & Afflerbach, 1995). Studies of reading through think-aloud studies to examine how students complete a cloze exercise (Bridge & Winograd, 1982), comprehend text (Caldwell & Leslie, 2010), complete a comprehension test (Campbell, 1999), summarize (Brown & Day, 1983), solve problems (Cheung, 2009) and read disciplinary texts (Hartman, 1995; Brill et al., 2004; Shanahan & Shanahan, 2008b) are representative of the types of studies reviewed in Ericsson and Simon's work (1993) which situated the process with respect to information processing theory.

The underlying constructs of information processing theory are long-term and short-term memory (Simon, 1978). Procedural and declarative knowledge comprise long-term memory while the thoughts that are temporarily in the mind comprise short-term memory. As one reads, for example, short-term memory is activated as the words on the page are read while long-term memory may be activated by a stimulus such as a word or picture to bring about a mental image (Simon, 1978). The think-aloud protocol can capture much of the internal workings of memory as the reader verbalizes these images and possibly relates the new information to information in long-term memory (Simon, 1978).

Studies of reading text have experimented with various formats for gathering information on the participants' thought processes as they interact with text. Using procedures that do not require students to explain or elaborate on their thoughts such as a think-aloud have been found to be the most non-reactive and are preferred methods for assessing cognitive strategies (Bannert & Mengelkamp, 2008; Fox et al., 2011). Ericsson and Simon (1993) noted that asking students to describe their thinking processes is not a reliable assessment of the processes actually used. Many students may not have the metacognitive ability to assess their own processes. In the present study, participants were only asked to think-aloud, not to attempt to describe or otherwise interpret their thoughts.

The focus on methods and instructions to participants in think-aloud studies that reduce their cognitive load and allow the natural processes of thinking to come through have emerged since the 1980's (Caldwell & Leslie, 2010; Ericsson & Simon, 1993; Pressley & Afflerbach, 1995; Priede & Farrall, 2011). Caldwell and Leslie (2010), for example, in studying middle school students reading expository text in social studies and science, compared the effect of thinking aloud to recall and question answering methods. Students were prompted to think-aloud during each paragraph at designated stop points and were told that after reading they would be asked to tell the researcher about the passage as if they had never heard it before. Priede and Farrall (2011), in reviewing think-aloud and verbal probing interviews, also concluded that think-aloud procedures are more effective in eliciting the interviewee's thoughts in his own words rather than interfering with his thought processes by posing a question.

Think aloud studies have proved useful in providing insight into the cognitive processes students employ during reading. In reading narrative texts, good readers generally provide more information regarding higher-level thinking processes than below average readers who may offer more responses but at a basic cognitive level (Janssen et al., 2006). Few studies focus on high school students' reading scientific of text, and none focus solely on average and below average readers reading of scientific text. While a traditional think-aloud where there are no prompts may not elicit much information from these students, allowing students to type responses or draw graphic organizers may offer more insight into what below average readers do (Munoz et al., 2006). Below average students may also divulge more information regarding thinking processes when prompted throughout the reading although some feel such prompting could be a confounding variable (Priede & Farrall, 2011; Fox et al., 2011). In order to elicit participants' reading processes without influence, no prompting was utilized in the think-aloud portion of the study, however, in order to elicit information regarding a participant's ability to utilize specific processes when reading scientific text, the SCLA was administered following the think-aloud. The information from the SCLA was used in triangulation of the data.

Below average students may also benefit from instructions regarding relevance of the text that they are about to read in a think-aloud since elaborations and seductive details included in text can garner more attention and indicate importance to the less skilled reader and interfere with comprehension (McCrudden et al., 2010; Rottman & Keil, 2011; Peshkam, Mensink, Putnam, & Rapp, 2011). However, in order to control any effects to which differences in instructions for each group could contribute, all participants in this study received the same instructions for the think-aloud protocol. An oral summary followed the think-aloud in order to capture data on comprehension that was used in triangulating the data. The triangulation process allowed the processes of frustration level readers, in particular, to be more fully examined.

In administering a think-aloud, consideration must also be given to the type and number of texts to be read by participants. Hartman (1995), in seeking intertextual links made when reading multiple texts, had participants read five selections. Other studies focus on a single text for the purpose of gaining information about comprehension (Brill et al., 2004). Two selections were selected for inclusion in the present study in order to provide varied text structure and to avoid fatigue that may accompany reading additional texts in one session, additionally the text selections were used to examine whether or not text structure played a role in comprehension (Kendeou & van den Broek, 2007).

Analysis of transcripts from think-alouds can be based on previous coding themes or as with the current study can follow a grounded theory approach in which codes emerge from the data (Creswell & Plano Clark, 2007). The unit of analysis is often a sentence or phrase (Pressley & Afflerbach, 1995). Analysis of transcripts in the present study was based on sentences or completed thoughts.

In Caldwell and Leslie's (2010) study of middle school students reading expository text in social studies and science, think-aloud transcripts were coded using clauses that were identified as paraphrases, inferences, topic statements, and meta-comments based on work by Trabasso and Magliano. Transcripts of college undergraduates' reading of a physics text were coded, a scheme the researcher established in earlier studies, a scheme that coded statements according to the cognitive processes readers engaged in during reading such as: comprehension monitoring, associations, intrasentential connections, correct inferences, incorrect inferences, and conceptual change. Such *a priori* coding was not conducted in the current study; however, information gained from previous studies informed the discussion found in Chapter 5 of this study.

Strategic Content Literacy Assessment (SCLA)

The Strategic Content Literacy Assessment (SCLA) is an informal assessment of reading used to target skill with discipline-specific cognitive practices (Alvermann et al., 2013). The assessment was developed based on the Standard Reading Assessment created by Brownlie, Feniak, and Schnellert (2006) as a means to assess the reading practices of students reading discipline-related texts. An assessment can be created by the classroom teacher through selection of several discipline-specific cognitive tasks to target. Several cognitive tasks that are easily adapted to the SCLA for the various disciplines include summarizing of the text, making inferences and intratextual connections, selecting of relevant information, and connecting to prior knowledge (Alvermann et al., 2013). A text related to the content is selected and questions are designed to elicit the targeted tasks. For the purposes of this study, a passage from the biology textbook used in the research site was selected. The topic of the selected passage was prokaryotic cell structure. This topic was selected because it related to the both the cloze and think-aloud topics but the content was not discussed in the previous instruments specifically. The passage was 232 words in length, contained 22 content vocabulary terms and was found to have a Lexile level of 1070 (see Appendix F). After students complete the assessment, responses can be scored using a teacher-developed rubric (see Appendix G-I) that assesses responses on a scale of 1-5, for example, to indicate degree of facility with the targeted cognitive processes (Alvermann, et al., 2013). The results of the analysis inform instruction on tasks that need to be strengthened as well as providing a baseline of disciplinary skill (Alvermann et al., 2013; Colwell, 2012).

The cloze and SCLA are effective tools that classroom teachers can easily use to assess students' ability to understand scientific text, however, understanding the finer literacy processes a student uses may not be discovered using these assessments. More detailed information regarding literacy processes can be obtained through think-aloud studies (Ericsson & Simon, 1993; Pressley & Afflerbach, 1995). The information obtained through the SCLA was used to triangulate the data from the think-aloud protocols along with data collected from the questionnaires and oral summaries.

Sampling Procedures

With permission granted by the Institutional Review Board, school district, school, and participants/parents, a convenience sample (Flick, 2002) of thirty-five students was selected from regular education high school students who volunteered to participate in the study (students with diagnosed learning disabilities who attend academic support classes were not be included in this study). The age of participants ranged from 14 to 18 years, representing students in their freshman through senior years of high school. The majority of participants were 16 years of age and in their junior year of high school. The majority of participants were also currently enrolled in a chemistry course and six participants were concurrently enrolled in two science courses.

Each participant returned the parent consent and child assent form prior to participating in data collection. A total of 32 participants completed both phases of data collection. Three participants completed a portion of the data collection but did not complete both sessions; therefore, the data from those participants were not included in the following chapter. Data were collected in the form of a questionnaire, cloze test, think-aloud, oral summary, and SCLA.

Students were recruited for participation through science classes. Students were presented with a flier explaining the study and how they would be compensated for their participation if they chose to volunteer. Students who volunteered were given permission forms for their parents to sign as well as a child assent form for them to sign. Two informational sessions were held for any parents who wanted more information prior to signing the parent permission form. No parents attended the informational sessions. Students who completed the entire process were offered a $10 gift card or verification of hours of service. All participants were entered into a drawing for a $25 gift card which was drawn at the end of the data collection period.

Research Procedures

Participants who returned parent permission and child assent forms were administered a demographic questionnaire and a cloze test (Taylor, 1956; Alvermann et al., 2013) that was used to divide participants into achievement groups in the first phase of the study. The second phase of the study involved participants completing a think-aloud protocol and an oral summary for two selections of scientific text followed by completion of an SCLA. All data collection occurred in the classroom or lab of the researcher either after school or during a participant's free period. Participants were not removed from instruction to participate in this study. Although both phases of the study were untimed, the first phase took participants 45 minutes to one hour to complete and the second phase took 1-1.5 hours to complete.

Phase I Data Collection

The questionnaire was administered to students first to collect demographics such as age, sex, and grade level as well as information regarding their reading habits outside of school and subject area likes and dislikes. The questionnaire also asked students for their current class schedule for the purposes of locating students during the school day if needed, as well as identifying current science course placement (see Appendix A).

After completing the questionnaire, participants were trained with a sample cloze assessment and were provided an example to complete for practice. Participants were then asked to complete a cloze assessment on the topic of the cell cycle created from a sample of text from the current biology textbook (see Appendices B & C). Cloze assessments were scored and ranked by percentage of exact matches (Greene, 2001;

O'Toole & King, 2011). The scores were used to sort students into achievement groups that were used as the basis for comparison of the processes used by the different groups. Groups were categorized as frustration level, instructional level, or independent level with the groupings reflecting the difficulty level of the text for the reader with text being considered too difficult, appropriately challenging, or easy to read respectively (Bormuth, 1968). Cloze test scores based on exact matches of 40 percent or lower indicated frustration level readers, 40-60 indicated instructional level readers, and scores above 60 indicated independent level readers (Alvermann et al., 2013). Analysis of cloze tests placed five participants in the frustration level group, 15 in the instructional level and 12 in the independent level reader groups.

Phase II Data Collection

The think-aloud protocol required participants to read two selections of scientific text. In order to assess students' processes in a manner that is applicable to the majority of science classrooms, participants were presented with a text passage from their biology textbook (Biggs et al., 2008), along with an article from *Discover* (Zimmer, 2011). These texts were selected due to their availability to students and the features of the text presented in each; for example, the textbook and *Discover* selections offer text written by disciplinary experts and feature visuals such as diagrams and graphs. The Lexile level for the textbook selection was determined to be 1100 and the *Discover* article had a Lexile level of 1260; these levels fall within the high school grade band on the Common Core Standards for Literacy in Science and Technical Subjects (NGA, 2010b).

In determining topics for selections, it was decided to use a textbook selection on a topic that students would not have yet studied as part of the Biology 1 curriculum and an article where participants would have a small degree of prior knowledge. In order to determine how students approached new or slightly unfamiliar topics in science, a topic was sought that students would have some general knowledge of but they would not have yet studied it in depth. Also important in this selection was selecting a topic where students would have a foundation for learning. The textbook topic of viruses was selected as the textbook topic since students are familiar with common viruses but the topic had not yet been studied in depth since it is not included in the Biology 1 course curriculum. Students had studied the structure of cells and cell replication which provided a frame of reference for learning about the structure and replication cycle of a virus. The topic selected for the *Discover* article was the brain (Zimmer, 2011). Participants learned about the nervous system in seventh grade and studied cells in the first semester of Biology 1 which provided a background for understanding the concepts of the selected article, "The Brain; Maybe You Do Need a Hole in Your Head to Let the Medicine In" by Carl Zimmer (2011).

The order of texts was counter balanced to control for threats to internal validity that could occur in the event that one text may provide background knowledge for another, which in turn, could affect processes utilized. Participants were audio recorded and video- taped during the protocol in order to examine any nonverbal activities that might have occurred. After audio and video tapes were transcribed, the recordings were erased to protect the identity of participant in accordance with the IRB- approved permission forms.

Using a script (see Appendix D) to ensure consistency in instructions given, participants were asked to think-aloud as they silently read and were informed they would be asked to provide an oral summary after reading each passage (Hartman, 1995; Pressley & Afflerbach, 1995). Participants were provided a demonstration of the think-aloud protocol process before they began reading and were given an opportunity to practice with a selection of text from the biology textbook.

After having an opportunity for practice, participants read each selection and verbalized their thoughts without prompting from the researcher. Participants who inquired whether or not they should read aloud were told to read as they would if completing a homework assignment; therefore, several participants chose to read the texts aloud. At the end of each selection, participants were asked to close the passage and provide an oral summary of the text so that I could assess their comprehension of the text.

Participants were asked to complete a SCLA as the final portion of the study (see Appendix E). Participants were allowed to view the text as they answered questions in order to provide information on their facility with the targeted literacy processes when prompted by a question. The literacy processes assessed by the SCLA were inferencing, metacognition, summarization, connections to prior knowledge, and vocabulary acquisition.

Data Analysis

Analysis of data from phase one of the study involved scoring the cloze assessment and recording data from the questionnaire for each participant. Cloze assessments were scored for the percentage of correct matches and were used to divide participants into achievement groups based on their ability to read the type of text under study using the criteria provided by Alvermann, Phelps, and Ridgeway (2013).

Phase two data analysis involved analyzing the think-aloud data, oral summaries, and the SCLA for each participant. Transcripts were transcribed and analysis began with open coding to establish initial categories. Individual transcripts were reviewed using open coding whereby codes were created for the processes noted in the think-aloud data (Glaser & Strauss, 1967). Transcripts were analyzed line by line. Codes were given names to describe the processes observed. While a pre-established coding system was not used, emerging categories consistent with competencies defined the Common Core Standards (NGA, 2010b) were named to reflect the terminology in the documents for consistency and to facilitate explanation of the data with respect to these documents (see Appendix J). In addition, code names reflected processes discussed in the literature (Glaser, 1978) such as those described by Pressley and Afflerbach (1995). Constant comparison methods were utilized to analyze transcripts in order to determine when categories were saturated for the entire set of data and to ensure consistency within a category (Glaser & Strauss, 1967). Transcripts for both reading selections were reviewed concurrently. After codes were established, transcripts were analyzed to determine the frequency of usage and the number of participants who utilized each process by achievement group and by text. With the use of a rubric developed by the researcher, summaries of the reading selection were scored (see Appendix E) based on main idea statements and details provided, as well as how well the details were explained. SCLA responses were scored using a rubric (see Appendices G-I) developed by Alvermann, Gillis, and Phelps (2013).

Summary

Working from a symbolic interactionist perspective whereby students' constructions of meaning for texts they read is result of their interactions with peers, teachers, texts, and the environment, qualitative methods were employed to ascertain the processes high school students utilize when reading scientific text. The processes students use when reading scientific text reflect experiences provided by teachers that have enabled interaction with peers, as well as the environment in which the content is situated. A cloze assessment provided a basis for creating three achievement groups based on reading level. Processes utilized emerged from the data collected during a think-aloud protocol during open coding. The data collected from the think-aloud were triangulated with questionnaire, oral summary, and SCLA data. The results of data analysis are presented in Chapter 4 and a discussion of the implications for instruction with respect to situated learning theory is presented in Chapter 5.

CHAPTER FOUR

PRESENTATION OF FINDINGS

The questions that guided this study were as follows:

1. What processes and cognitive skills do students use when reading scientific text?

2. How do students of varied achievement levels differ in their reading of scientific text?

These questions served to structure the presentation of the data as overall and group differences were examined. Participants were grouped based on results of the cloze test, which are presented in the following section. Next, information provided by the participants on the questionnaire regarding reading habits and favorite subjects are presented to provide insight into their interests. Finally, data regarding participants' reading processes that emerged during the think-aloud protocol are presented. Data from the SCLA and oral summaries follow for the purpose of triangulating the data.

Cloze Tests

Participants completed a cloze assessment on the topic of the cell cycle. Cloze tests were scored and informed the initial categorization of participants into frustration reader (*Frus*), instructional level reader (*Ins*), and independent level reader (*Ind*) achievement groups using a scoring guide as suggested by Alvermann, Gillis, and Phelps (2013). Upon review of scores of the cloze test, five participants scored below 40% which placed them in the frustration level reader achievement group. Fifteen participants scored between 40% and 60%, placing them in the instructional level reader achievement group and the remaining 12 participants scored above 60% which placed them in the independent reader achievement group. The groups resulting from the cloze test were used to compare questionnaire, think-aloud, SCLA, and summary data. It is acknowledged that participants, especially those who were near a cutoff score, may place in a different achievement level with a different text. It is also acknowledged that had synonyms been accepted, some participants may have scored higher.

Questionnaire Data

The questionnaires solicited demographic information, as well as information regarding participants' self-assessment of reading ability, reading habits outside of school, and favorite school subject. The roles of interest in reading and the subject area were considered in analysis of the think-aloud data. Participants' current science course placements were also indicated. Students may be placed in technical prepatory (TP), college prepatory (CP), or honors (H) level courses. In the school that served as the research site, the following progression of introductory science courses is followed: physical science (CP Phys Sci or H Phys Sci), biology (CP Bio or H Bio), chemistry (TP Chem, CP Chem, or H Chem), physics (CP Phys or H Phys). A few participants were concurrently enrolled in chemistry and biology. Results of the questionnaire are presented by achievement group in tables 4.1, 4.2, and 4.3. All names of participants presented in this study are pseudonyms.

Table 4.1

Frustration Level Questionnaire Responses

Name	Grade	M/F	Current Science Course & Level	Cloze Score	Are you a good reader?	Like to read?	Preferred type of reading material	Books read outside of school/year	Favorite subject
Tina	11	F	TP Chem	14	Yes and no	No	Mysteries, gun/weapons	1 - 2	Art
Lindsay	11	F	CP Chem	31	Yes	Yes	Fiction, magazines	3 - 4	History
Jackie	11	F	CP Chem	33	No	Yes	Romance novels	2 - 3	English
Kate	11	F	TP Chem	33	Yes	Yes	Nicholas Sparks books	3 - 4	History
Jake	11	M	CP Chem	36	No	No	Text messages	0	Math, Biology

Table 4.2

Instructional Level Questionnaire Responses

Name	Grade	M/ F	Current Science Course & Level	Cloze Test	Are you a good reader?	Like to read?	Preferred type of reading material	Books read outside of school/year	Favorite subject
Chance	11	M	CP Chem	42	No	No	No response	1 - 2	Math
Cody	11	M	CP Chem	44	Yes	Yes	Non-fiction, automotive	20	Math
Anna	10	F	CP Bio	44	Yes	Yes	Mysteries, crime	30 - 40	Science
Autumn	12	F	CP Chem	44	Yes	Yes	Romance, young adult, biographies	50	English
Brad	11	M	CP Chem	50	Yes	Yes	Harry Potter,biographies	14	Science
Cindy	11	F	CP Chem	53	Yes	No	Text messages and Facebook	0	Math
Kevin	11	F	CP Chem	53	Yes	Yes	Novels, nonfiction	10	Math
Lupe	10	M	CPChem/ CP Bio	55	Yes	No	History, war	1	Math/history
Wilson	11	M	CP Chem	56	Yes	Yes	Sports books	3	History
Francis	11	F	CP Chem	56	Yes	Yes	Modern science fiction	7 - 8	Art
Allen	11	M	CP Chem	58	No	Yes	Sports	0	None
Priya	10	F	H Chem/ H Bio	58	Yes	Yes	Romance, autobiographies	30	English
Monica	11	F	CP Chem	58	Yes	No	Mystery, Spark notes	1 - 2	English
Jim	11	M	CP Chem	58	Yes	No	None	0	History
John	11	M	CP Chem	58	Yes	Yes	Religious, nonfiction	3	History

Table 4.3

Independent Level Questionnaire Responses

Name	Grade	M / F	Current Science Course & Level	Cloze Test	Are you a good reader?	Like to read?	Preferred type of reading material	Books read outside of school/year	Favorite subject
Jack	11	M	CP Chem	61	No	No	Fiction, comics, magazines	1	Graphic design
Steve	11	M	CP Chem	61	No	Yes	Science fiction, fantasy, historical fiction, poetry	3 - 6	Science
Rebecca	11	F	CP Chem	61	Yes	Yes	Mystery, romance novels	2 - 3	Math
Alana	10	F	CP Bio	64	No	Yes	Fantasy, nonfiction	60	German, math
Whitney	11	F	CP Chem	64	No	Yes	Graphic novels, magazines	7	History
Shannon	10	F	H Chem/H Bio	67	Yes/no	Yes	Fiction, humor, nonfiction	15 - 30	Science
Brody	10	M	CP Chem	67	Yes	Yes	Science fiction, graphic novels, mysteries, suspense	2 - 3 series	Math
James	11	M	CP Chem	72	Yes	Yes	Science fiction, fiction, documentaries	5 - 10	Biology
Thomas	10	M	CP Bio	78	Yes	Yes	Fantasy, historical	Not many	History
Amit	11	M	CP Chem	81	Yes	Yes	Fiction	10	Math
Mary	10	F	CP Bio	82	Yes	Yes	Fiction	50+	German, math
Stephanie	10	F	H Chem/ H Bio	84	Yes	Yes	Fantasy, romance	40 - 50	Music

Reading Habits

The number of books participants reported reading outside of school varied from zero to over 50 per year. Six participants (1Frus, 4 Ins, and 1 Ind) reported that they do not read outside of school, 17 participants (4 Frus, 6 Ins, and 7 Ind) reported that they read ten or fewer books per year, and four (1 Ins, 3 Ind) reported reading more than 40 books per year. None of the frustration level readers reported reading more than five books per year outside of school.

The types of reading material participants preferred to read in their free time, if they liked to read outside of school, varied with fiction (fantasy, mystery, romance, science fiction, general fiction) genres cited by 66% of all participants. Other types of reading material noted were nonfiction genres (sports, religious, biography, automotive, historical, magazines, text messages, Facebook), graphic novels, and poetry cited by 28% of all participants. The most avid readers (Autumn-Ins, Alana-Ind, Mary-Ind & Stephanie-Ind) reported a preference for fantasy and romance genres. The frustration level readers reported reading a preference for fictional material with the exception of one participant who noted that he did not read books. Instead, he said he read text messages. Four instructional level readers also noted that they did not choose to read outside of school. Of the instructional level readers who did report reading outside of school, the majority (55%) preferred a type of fiction material. Only one independent level reader noted that they did not like to read but all of the independent level readers reported that they did read outside of school with most (92%) having a preference for fiction.

Participants were asked if they considered themselves to be good readers. Twenty-two participants responded that, yes, they thought of themselves as good readers but two noted that it depends upon the text. Other reasons noted for their belief that they were a good reader included getting good grades, the ability to read quickly, and the ability to pronounce words. The ten participants who did not consider themselves to be good readers cited frustration, difficulty with comprehension, and boredom as contributing factors.

Tina (Frus): When I read out loud for the class, I usually stutter, but I'm pretty okay reading by myself. I just get distracted easily.

Stephanie (Ind): I am good at reading quickly to myself and at a good pace aloud. I can easily pronounce and identify words I don't know.

Thomas (Ind): I read faster than most kids.

Steve (Ind): Compared to others in my AP language class, I would consider myself a slow reader.

Wilson (Ins): I can read it smoothly and I can normally understand everything that is going on.

Cody (Ins): I've always had a high reading level. I feel I can pronounce and know the meaning of larger vocabulary.

Amit (Ind): I'm in honors and CP (college prep) classes and I do well.

Francis (Ins): I have an A in English and I've always been above reading level.

Rebecca (Ind): I usually score well on tests pertaining to literature.

Jake (Frus): I zone out when I read." [I don't like to read] things too hard or too boring.

Whitney (Frus): I don't put a lot of effort into books. I read for class because they are not books of my choice.

Chance (Ins): I can't focus good enough.

Favorite Subject in School

Participants were surveyed as to their likes and dislikes for school subjects. Participant comments supporting their choices were mostly limited to general statements of boredom or difficulty for subjects they disliked. Statements focused on interest and relevance for the subjects they liked. Participants were not specifically asked about their opinion of science class in order to get a more accurate picture of who actually favors science, as it was assumed by the researcher that more students would respond favorably when specifically asked specifically about science since the researcher was known to them as a science teacher in their school.

Math and social studies/history were the two most favored subjects overall. Math was selected by ten participants (1 Frus, 5 Ins, 4 Ind) and social studies/history was selected as the favorite subject of nine participants (2 Frus, 5 Ins, and 2 Ind). English was the favorite subject of four (1 Frus, 3 Ins) participants, as was science (1 Frus, 1 Ins, and 2 Ind). Seven participants (1 Frus, 1 Ins, and 5 Ind) selected arts and languages as their favorite subject area. Three of the most avid readers selected arts and languages as their favorite.

Reasons given for disliking a particular subject included disinterest and difficulty level, as well as feelings of inadequacy. Other participants expressed dislike due to perceived difficulty.

Comments regarding a dislike of English:

Lupe (Ins): We read boring books.

Jake (Frus): I hate getting my grammar corrected.

Amit (Ind): I don't like to read or write essays.

Brody (Ins): I just don't seem to be good at it like the others.

Comments regarding a dislike of Math:

Lindsay (Frus): I don't understand right off the bat.I have to put twice as much effort into it as my other classes.

Kate (Frus): I've never been good at math.

Wilson (Ins): It takes a lot of time to solve some problems.

Steve (Ind): I often find it incomprehendible *[sic]*.

Comments regarding a dislike of science:

Jim (Ins): Science courses because they seem to be my hardest.

Alana (Ind): I feel like they just aren't needed for my life.

Comments regarding a dislike of history/social studies:

Kevin (Ins): Boring!!!

Monica (Ins): It's boring and it's too much to remember.

Participant comments supporting their pick for favorite subject included interest in the subject in general, feeling that it will benefit their anticipated career, as well as success in course work. Several participants cited the enjoyment of learning about the past with regard to history (Jim-Ins, John-Ins, Wilson-Ins, and Whitney-Ind). Participants who liked arts and languages focused comments on the ability to express themselves. Several participants cited the connection of their favorite subject to career plans. Other participants' comments were based on success in the subject

Comments regarding art as the favorite subject:

Francis (Ins): I like creating rather than memorizing.

Tina (Frus): I like being creative.

Comments regarding English as the favorite subject:

Priya (Ins): I either want to be a writer or a lawyer, so I feel like this class benefits me the most.

Autumn (Ins): English is my favorite because I like to read.

Comments regarding Math as the favorite subject

Jake (Frus): I like numbers.

Alana (Ind): Math, because it makes sense. There is a right and a wrong instead of like in science.

Comments regarding Science as the favorite subject:

Brad (Ins): It's the field I want to go into.

Anna (Ins): I want to go to college for forensics.

Shannon (Ind): There's a lot of visual activities and easier to understand for me.

Qualitative Analysis of Think-aloud

Audio recordings of the think-aloud protocols were transcribed. Video recordings that were made simultaneously were reviewed for any nonverbal processes that may have occurred for inclusion in the transcript. Transcripts were uploaded into NVIVO 10 for initial coding. Using open coding procedures as described by Glaser and Strauss (1967), transcripts were analyzed for processes, and codes were applied to describe the processes as shown in Appendix J. Using the lens of disciplinary literacy, codes were sorted into categories reflecting the practices associated with disciplinary literacy (Shanahan &

Shananhan, 2008b; Shanahan et al., 2011).In reviewing transcripts, approximately one-third of the codes identified aligned with text structure and prior knowledge concepts, representing 49% of all statements made during the think-aloud. Comments coded for reading patterns and comprehension strategies comprised an additional 9% and 10% of all statements made respectively. The following section will present processes grouped under text structure, prior knowledge, reading pattern, and comprehension monitoring strategies.

Text Structure

Codes for text structure were further analyzed and processes within the text structure category were refined into three subcategories: (i) numbers, color and font, (ii) vocabulary, and (iii) graphics. Table 4.4 shows the average frequency per participant with which each process coded under text structure was utilized by each achievement group.

Numbers, Color, and Font. As some participants read the texts, they noted the presence of features of the text such as the presence of numbers, the color of the text, or a change in font. The brain text began with a cued statement in large, bolded type and included one colorful graphic. The viruses selection was a typical textbook selection filled with colored and bold headings, subheadings, and bolded or highlighted vocabulary. Participant statements regarding these specific features of text, along with

Table 4.4

Mean Frequency of Statements Per Participant for Text Structure

Code	Frustration M(SD)	Instructional M(SD)	Independent M(SD)
Number, Color and Font			
Numerical reference	0.0(0.0)	0.40(0.70)	0.33(0.49)
Color or Highlight	0.20(0.45)	0.60(0.83)	0.58(1.51)
Font	0.20(0.45)	0.93(1.8)	1.3(2.9)
Vocabulary			
Vocabulary	1.4(2.6)	2.0(1.7)	2.6(2.1)
Graphic Reference			
Number, title, content	2.0(2.1)	2.5(2.1)	3.4(1.7)
No identifying information	0.0(0.0)	1.6(2.6)	1.0(0.85)
Skips graphic	0.0(0.0)	0.40(0.83)	0.75(0.97)
Skims graphic	0.0(0.0)	0.13(0.35)	0.25(0.45)
Reads caption	0.60(.55)	0.80(1.0)	0.33(0.49)
Views after prompt	0.80(1.8)	0.47(0.64)	0.42(0.90)
Moves text ↔ graphic	0.0(0.0)	0.53(1.3)	0.08(0.29)

numerical references and statements focusing on highlighted terms or change in font represented approximately 4% of all responses.

Lindsay (Frus): The first thing I look at is that picture in green and red. I guess the color is attracting me because everything else seems to be black and white.

Jim (Ins): Then I skip to the bold terms that are highlighted and read the sentence before it and the sentence after it.

Cindy (Ins): I don't know what a nanometer is. Oh, it says it is one billionth of a meter. It's really, really tiny. I found it interesting that it would take about 10,000 cold viruses to fit on the period at the end of a sentence.

Monica (Ins): Then, I look at the big headings, especially the colored headings, they pop out nicely.

John (Ins): I turn the page and I immediately see the highlighted words and I go to the red subtitle 'Lytic Cycle' and I start reading. I go down and look at the red letters, 'the Lysogenic Cycle' and [I] keep reading.

Rebecca (Ind): I see the word 'viruses' highlighted. Then, I see that there is red text that says 'virus size'.

Stephanie (Ind): It says that a virus can be from 5 to 300 nanometers which is really, really, small.

Vocabulary. Vocabulary references contributed to approximately 5% of the total statements and were more frequent with the textbook selection which highlighted content vocabulary or listed key terms in the margins. The focus of this code was the mention of vocabulary whether it was a list of terms or a specific term. The brain article vocabulary was not highlighted. Only four participants commented directly on vocabulary when reading the brain article as compared to 23 with the viruses selection.

Terms that elicited comment in the brain article included erythropoietin, transferrin, and neurological. The thought processes that were prompted varied across achievement groups. Terms that elicited comment in the viruses selection included *virus, capsid, lytic cycle, exocytosis,* and *lyse*. Only two frustration level readers specifically noted vocabulary. Frustration level comments were limited to associations with familiar content. Instructional level readers overall focused on efforts to make sense of unfamiliar terms they encountered using root words and context clues. Independent level readers took more time to look at vocabulary in the margins and bolded terms prior to reading.

Independent readers also spent more time reviewing vocabulary after reading than instructional or frustration level readers.

> *Lindsay (Frus):* When I read the word neurological, I think of neurons and stuff like that….There's this word 'capsid,' it sounds like capsule, so that's kind of the way I think of it because its' the outer layer of the virus kind of like a capsule holds things in it.

> *Francis (Ins):* They keep repeating some of the same words and terms, so I think they might be important because of that.

> *Wilson (Ins):* I read the text and make sure when I come upon a vocab word I make sure I know exactly what it means.

> *Brody (Ind):* I was going to use root knowledge of 'to move', but it tells you what it is right there – reread a little bit there.

> *Rebecca (Ind):* I see that there's a word highlighted and bolded and it says capsid and I don't know what that means, so that tells me that I have something I need to be looking for. When I get to the vocabulary word I realize that although I just read the sentence it is in, I still don't really understand what a capsid is, so I'm going to go back and read the sentence now that I have gotten back to the word.

Graphics. References to graphics comprised approximately 20% of all statements contributed during the think-aloud. The brain article featured only one graphic while the viruses selection featured four. Statements initially coded "graphic reference" were further refined based on the nature of the reference resulting in the following codes: (i) graphic reference-specifies graphic by number, title, or content; (ii) graphic reference-no identifying information; (iii) graphic reference-skips graphic; (iv) graphic reference-skims graphic; (v) graphic reference-reads caption; (vi) graphic reference-views after prompt from text; and (vii) graphic reference- moves between text and graphic.

Title, number, or content. Nineteen participants made a graphic reference that identified the graphic by title, number, or content when reading the viruses selection. Only three participants identified the lone graphic in the brain text in a similar manner.

> *John (Ins):* It references a table that has different diseases that are used by viruses so I'll look at those.
>
> *Jim (Ins):* I go down here and look at this chart at the bottom, Human Viral Diseases.
>
> *Lindsay (Frus):* Now I'm looking at the chart and looking at all the diseases on it.
>
> *Kate (Frus):* I'm on the last page and I was just looking through figure 18.13, Visualizing Viral Replication.
>
> *Brody (Ind*): Right now I'm starting to look at this picture of the cells and the brain blood vessel first.
>
> *Kevin (Ins):* Now I'm looking at the picture of cells in the brain blood vessel.

No identifying information. Some participants made references to a graphic that did not identify the title number or content. Instead, participants simply referenced it with a general term such as *chart* or *picture*. Six participants reading each text made such references.

> *Monica (Ins):* It does have one huge picture up in the corner that caught my eye first.
>
> *Jack (Ind):* Looking at the picture.
>
> *Jake (Frus):* Now I'm looking at the picture.

Skips graphic. Three instructional and four independent level readers acknowledged skipping one or more graphics in the viruses selection. Only one instructional level reader and one independent level reader skipped the graphic in the brain article. Mary (Ind), who did not verbalize her thoughts, was observed by the researcher while reading. She underlined every word with her pencil and did not stop to view the graphic. None of the frustration level readers acknowledged skipping visuals in either text

Allen (Ins): On the last page, I didn't read it because it was just a big chart with picture.

Thomas (Ind): I don't need to look at the history of smallpox, I don't care.

Skims graphic. Slightly more attention was given to the graphics by participants who acknowledged that they skimmed one or more graphics. One instructional and three independent level readers acknowledged skimming a graphic in the viruses selection.

Steve (Ind): I glance over the table at the bottom.

John (Ins): I go to read but the chart catches my eye and I look at it – I just glance at things on the chart.

Reads captions. Several participants reported reading the captions accompanying a graphic. In the brain article, three frustration level readers noted reading the caption accompanying the graphic. Seven instructional level and three independent level readers also acknowledged reading the captions in the brain article.

Lindsay (Frus): I read the little caption that describes the picture.

Jake (Frus): Now I'm looking at the picture. I'm reading the caption.

Jackie (Frus): The picture, then the caption.

Cody (Ins): As you move on to the second page my eyes go straight to the picture and the caption below it.

Stephanie (Ins): In here on the last page, it shows the cycles that the virus goes through. This caption kind of explains that everything in the lytic cycle happens in the cytoplasm.

View after prompt. The viewing of graphics was noted by many participants to occur after prompting within the text. No participants noted prompting from the text as a stimulus for viewing the graphic in the brain article. One frustration level reader, seven instructional, and two independent level readers noted prompts from the viruses text as the precursor to viewing one or more graphics.

> *Shannon (Ind):* When it says in Table 18.2, I look at it.
>
> *John (Ins):* I see a reference to a figure and I make a mental note to go back and look at it when this sentence is finished.

Moves between text and graphics. Moving between graphics and text is a practice of experts in the science discipline (Shanahan & Shanahan 2008b) and is a practice supported by the CCSS (NGA, 2010b). In reading the viruses text, only two instructional level readers acknowledged moving between text and the graphic in order to clarify their understanding of the material.

> *John (Ins*): I'm beginning to understand as I'm reading more and I look back at the picture.
>
> *Brody (Ind):* I'm looking at the figure of the lytic cycle to see if I can figure out what is going on while I'm reading about what is going on.

Prior Knowledge

Prior knowledge has been found to have a positive effect on comprehension of scientific text for both high and low skilled readers (Ozuru, Dempsey, & McNamara, 2009). Three codes relating to prior knowledge were identified in transcripts: (i) acknowledging familiar terms or content, (ii) recognizing unfamiliar material, and (iii) personal connections. Statements labeled with these codes comprised 10% of all statements made during the think aloud protocol. The average frequency per participant of statements related to prior knowledge were summarized in Table 4.5.

Table 4.5

Mean Frequency of Statements Per Participant for Prior Knowledge

Code	Frustration M(SD)	Instructional M(SD)	Independent M(SD)
Acknowledges familiar	1.2(2.2)	1.4(2.5)	1.3(1.8)
Personal connections	1.0(1.7)	1.1(1.5)	1.2(1.6)
Recognizes unfamiliar	.60(.89)	3.0(4.4)	1.2(1.4)

In reading the texts during the think-aloud, participants noted familiar and unfamiliar material. Knowledge placed under these codes excluded statements making a personal connection as those comments were grouped together. In reading the brain article, 19 participants specified that material was familiar.

Participants not only acknowledged what they knew but they also discerned what they did not know, indicating a degree of metacognitive skill. Eight instructional level readers and three independent level readers recognized unfamiliar material when reading the brain article.

The brain article elicited slightly more personal connections than the viruses selection. Many participants noted having relatives with some of the diseases mentioned in each of the text selections.

Acknowledges familiar content. In reading the brain article, 19 participants specified that material was familiar.

Allen (Ins): I noticed the word ultrasound because I know what an ultrasound is.

Lindsay (Frus): When I read the word neurological, I think of like neurons and stuff like that.

Amit (Ind): I kind of understand what Alzheimer's is as far as being a brain disease.

Monica (Ins): I remember doing replication of DNA and RNA and how the letters hook up with letters on the other side.

Brody (Ind): Just started reading this and I'm thinking about past classes hearing about viruses to see if I can connect anything I know to it about where viruses come from and their structure.

Jackie (Ins): A host cell is like a momma cell. It's going to, like, produce more.

Recognizing unfamiliar material. Participants not only acknowledged what they knew but they also discerned what they did not know, indicating a degree of metacognitive skill. Eight instructional level readers and three independent level readers recognized unfamiliar material when reading the brain article**.**

Thomas (Ind): I have no idea what syphilis is.

Monica (Ins): I don't know a lot about brain cancer, Alzheimer's and Parkinson's. I've heard of them but I don't know what causes them or the effects they have.

Lindsay (Frus): There are some words like 'bacteriophage' that I'm not familiar with. I'm not sure what it really is.

Jackie (Frus): I did not know AIDS was a virus.

Priya (Ins): I didn't know that a virus was not living.

Personal connections. The brain article elicited slightly more personal connections than the viruses selection. Many participants noted having relatives with some of the diseases mentioned in each of the text selections.

Jake (Frus): I remember that. Alzheimer's we talked about earlier and Parkinson's is what my granddad had.

James (Ind): It says *chicken pox* and it reminded me of when I was younger when I had chicken pox. It's pretty intense.

Lindsay (Frus): When I read that viruses can't be transmitted between different species, I think about how we don't get dog's diseases or cat's diseases, and if we have the flu we don't give it our pets.

Reading Pattern

The use of headings provides the reader with the text's topic structure. The texts read during the think-aloud protocol were at opposite ends of the spectrum with regard to the number of headings. The brain text included a topic sentence as a heading and the first sentence was bolded in a larger font. The separation of the body text was accomplished by using capitalized letters for the first line of each of the two subsections. The viruses textbook selection had a title followed by headings and subheadings every couple of paragraphs. The headings influenced the reading patterns of the participants.

Research on disciplinary experts reading discusses the patterns experts use when reading scientific text (Shanahan & Shanahan, 2008b). Several patterns of reading emerged through analysis of the think-aloud transcripts. Codes emerged for previewing headings, previewing author, skimming for preview, skimming for review, skipping text or graphic, and the overall order of reading. The order of reading code was further refined into the following: i) order of reading-graphics first, ii) order of reading-straight through, and iii) order of reading-break in pattern. When statements representing all codes referencing a pattern of reading were combined, they totaled 9% of all statements from the think-aloud. Table 4.6 shows the average frequency per participant of statements for codes related to reading pattern for the three achievement groups.

Table 4.6

Mean Frequency of Statements Per Participant for Reading Pattern

Code	Frustration M(SD)	Instructional M(SD)	Independent M(SD)
Previews headings	0.60(.55)	1.5(1.1)	1.1(1.2)
Previews author	0.20(.45)	0.13(.35)	0.08(0.28)
Skims for preview	0.0(0.0)	0.40(0.74)	0.25(0.62)
Skims for review	0.20(0.45)	0.13(0.35)	0.42(0.67)
Skips text	0.0(0.0)	0.80(1.4)	1.2(1.6)
Graphics first	0.80(0.45)	0.33(0.62)	0.33(0.49)
Reads straight through	0.20(0.45)	0.0(0.0)	0.25(0.45)
Break in pattern	0.0(0.0)	0.53(.52)	0.25(0.45)

Previews heading or author. Many participants began reading the texts by previewing the headings or author in the texts. Sixteen participants previewed the heading at the beginning of the brain article and fifteen participants previewed the headings in the viruses selection before reading the body text. In the brain article, the first sentence served as a heading as it was bolded and in a much larger font. Several participants focused on the heading statement when reading the brain article.

Kate (Frus): Okay, the first thing I'm looking at is the top, 'maybe you do need a hole in your head.

Wilson (Ins): First my eyes to the, I look at the bold text, the title of the page.

Whitney (Ins): I'm looking at the bigger text to see what it's going to be about.

Similarly, with the viruses text,

Steve (Ind): The first thing I looked at was the top of the page, starting with the bolded words.

Lupe (Ins): When I first open the book and look at the text we're told to read, I look at the subheadings and kind of skim through the pages we've got to read and then I'll go back and read the main idea to try to get a clue what it's about and then I'll start reading the main sections.

Lindsay (Frus): The first thing that I do is look at the word 'viruses' and I start reading.

James (Ind): The first thing my eye really picks up is the caption about Carl Zimmer.

Lupe (Ins): I look to see who wrote it and begin reading.

Kevin (Ins): I'm looking at the caption at the bottom of the page about Carl Zimmer.

Skims for preview. Several participants skimmed the texts for preview purposes. Four participants previewed the brain article by skimming. Five participants skimmed the viruses selection prior to reading. Brody (Ind) didn't verbalize his intent but was observed skimming through each page of the text prior to reading.

Monica (Ins): I'm looking at the paper now but it doesn't have a lot of pictures on it.

Jim (Ins): I just skim over all of this to get the basic idea.

Rebecca (Ind): I'm going to look back over where it says 'neuroscientists these days' and I'm going to see that this text is bigger than what's actually in the columns, so I'm going to skim through that.

Monica (Ins): Well, first I always look and see the pages I have to read because I really hate reading.

Wilson (Ins): I skim over it, look at everything to get a general understanding of what's going on and then start reading the text.

Brody (Ind) didn't verbalize his intent but was observed skimming through each page of the text prior to reading.

Skims for review. After reading, several participants chose to skim back over the text to review the content. One participant skimmed back over the brain article for the purposes of review and six reviewed the viruses selection. Jim (Ins) is the only participant who reviewed the brain article. He noted his purpose for skimming back over the article in saying, "I go back over and kind of scan the whole thing again to make sure I know what's going on." Participants' reasons for reviewing were based on a need to gain a better understanding of the material.

Jack (Ind): I'm skimming back through the page to see if there's anything I missed.

Monica (Ins): Now I'm flipping back and forth between pages because with all honesty, I don't know what I just read.

Lindsay (Frus): I went back to the first page and kind of skimmed through it again because I know I've got to give a summary on it, but usually I wouldn't…and that's probably why on tests I don't know the information quite as well because for me I have to read through things more than once to get it.

Skipping text. Rather than spending additional time previewing or reviewing text, seven participants skipped text in the brain article and thirteen skipped text in the viruses selection. Many participants who acknowledged skipping text skipped text in the margins or graphics, placing more focus on the body text.

Rebecca (Ind): I see at the bottom it says in bold, 'Carl Zimmer,' now I realize it isn't about anything, so I'm just going to go back and start reading now.

Allen (Ins): I didn't read the part where it talked about the biology writer.

Shannon (Ind): I start with 'Neuroscientists,' and I skip the beginning, 'maybe you do need a hole' part.

Steve (Ind): Usually I skip what's on the left, the review of vocabulary, new vocabulary and objectives.

Stephanie (Ind): Okay, then it has a lab down here and questions about it. Most of the time, I would just glance over it and wouldn't really analyze it or anything.

Allen (Ins): The timeline at the bottom of the page I didn't read.

Priya (Ins): The timeline of the history of smallpox is really long and I probably wouldn't read it.

Shannon (Ind): I don't look at the History of Smallpox. I don't read the Data Analysis Lab 18.1.

Graphics first. The order in which participants read through text varied. Four participants began the brain article by attending to the graphic and nine began the viruses selection by looking through the graphics first.

Lindsay (Frus): The first thing I look at is that picture in green and red. I guess the color is attracting me to it because everything else seems to be black and white.

Jackie (Frus): The picture, then the caption.

Chance (Ins): The first thing I look at is the picture.

Brody (Ind): Right not I'm starting to look at this picture of the cells and the brain blood vessel first.

Frustration level readers Kate and Jake and independent level reader Alana noted "table 18.2" first when viewing the text. Monica (Ins) and Kevin (Ins) noted, "I look at all the pictures first." Monica, who as previously established that she doesn't like to read noted that the "pictures are the best part of it."

Straight through vs. breaking pattern. Other patterns of reading exhibited during the think-aloud include reading straight through without previewing and breaking the pattern to reread text or read margin notes. One participant, Steve (Ind), began reading the brain article at the beginning and read it straight through, and two (Alana-Ind, Whitney-Ind) read the viruses selection straight through without previewing or tending to vocabulary or graphics prior to reading. Participants who did not follow the text straight through deviated to reread and look at margin notes. Six participants stopped to go back and reread material before reaching the end of the article in the brain article and seven participants did so during the viruses selection.

> *Wilson (Ins):* I didn't understand something so I made sure to go back over that a couple of times to make sure I understand it.

> *John (Ins):* It confuses me so I go back and read the first paragraph that discusses the blood-brain barrier.

> *Cindy (Ins):* And so now I'm going to go back to the first page and look at the subheading about Carl Zimmer.

> *Autumn (Ins):* Now I'm going to read this little thing about Carl Zimmer, the author.

> *Jim (Ins):* I read the vocabulary word over here on the side.

> *Wilson (Ins):* I read the extra things on the side.

> *Monica (Ins):* Now I'm looking at the careers in biology on the side. I usually never read those.

Comprehension Strategies

Strategies aiding comprehension contributed to 10% of the total statements made during the think-aloud. In addition to the strategies that demonstrated an active effort to understand the texts read, statements that demonstrated an unclear or lack of understanding often prompted use of the comprehension strategies. Comprehension strategies utilized demonstrated engagement with the text, as well as deliberate efforts to obtain a clear understanding of the material. The average frequency per participant of statements related to comprehension strategies were summarized in Table 4.7.

Table 4.7

Mean Frequency of Statements Per Participant for Comprehension Strategies

Code	Frustration M(SD)	Instructional M(SD)	Independent M(SD)
Difficulty with text/graphic	1.4(2.6)	0.40(0.74)	0.42(0.90)
Unsupported/incorrect claim	0.0(0.0)	0.20(0.41)	0.33(0.65)
Navigating	3.5(1.3)	3.2(4.2)	6.3(6.9)
Remark-random	1.0(1.2)	0.3(0.59)	1.1(2.4)
Remark-text based	1.0(.71)	1.5(2.8)	1.8(3.1)
Verbatim reading	0.40(0.89)	1.7(3.3)	3.2(5.0)
Intratextual connection	0.0(0.0)	0.40(0.91)	0.17(0.39)
Predicting	0.0(0.0)	0.57(0.85)	0.42(0.79)
Questioning	0.60(0.89)	0.87(2.1)	1.7(2.8)
Memorizing	0.0(0.0)	0.27(1.0)	0.0(0.0)
Seeking clarification	3.4(4.6)	2.8(3.8)	2.9(2.4)
Describing	1.8(2.4)	1.9(2.1)	2.6(1.8)
Paraphrasing	0.40(0.55)	2.7(4.5)	2.5(4.3)
Synthesis	0.40(0.55)	0.93(0.96)	1.3(1.5)

Codes for statements demonstrating a lack of understanding were as follows: (i) expresses difficulty interpreting graphic or text and (ii) unsupported or incorrect claim.

Difficulty interpreting graphic. Five participants (1 Frus, 1 Ins, 3 Ind) expressed difficulty interpreting a graphic when reading the viruses text.

> *Amit (Ind):* I guess I'm going to go back and read the lytic cycle and the lysogenic cycle because I barely know what's going on.

> *Monica (Ins):* This picture is kind of confusing. I don't know what I'm supposed to be looking at.

Frustration level reader Tina expressed the most difficulty in interpreting the graphic of the lytic and lysogenic cycle:

> Those sticks look like a pentagon on top of it, leaving a circle. The virus attached to the bacterial cell like a rubber band thing inside of a circle or a stick with a pentagon on top of it, stuck on it. The little worm thing goes down the stick into the circle. The worm blends into the rubber band. The one leaves and makes three of them with the worm not in it yet. It makes three with the worm in it and then goes all over again.

Difficulty interpreting text. Four participants article (3 Ins, 1 Ind) expressed difficulty interpreting text when reading the brain article. Three participants (1Frus, 1Ins, 1 Ind) expressed difficulty interpreting the text when reading the viruses text.

> *Jack (Ind):* It's kind of hard to understand.

> *Allen (Ins):* I kind of started skimming when it said blood-brain barrier because I didn't understand what it said very well.

> *Monica (Ins):* And now I'm flipping back and forth pages because with all honesty I don't know what I just read.

> *Jackie (Frus*): I have no idea what I just read.

Unsupported or incorrect claim. In addition to statements by participants indicating difficulty with text or graphics, four participants made statements that were incorrect and/or not supported by the text.

Stephanie (Ind): From previous knowledge I know it's a tender area and is not really that easy to get to either.

James (Ind): I heard that when you've had a cold and get over it, the next cold you get is not like the same bacteria or virus, or whatever. It's totally different.

Jack (Ind): There's no definition for lytic cycle which is strange.

Engagement with Text. Statements demonstrating engagement with the text were as follows: (i) navigating, (ii) remark random, (iii) remark text based, (iv) verbatim reading, (v) intratextual connection, (vi) predicting, and (vii) questioning.

Navigating. Fifteen participants (1 Frus, 6 Ins, 8 Ind) navigated their way through the text by indicating where they were focusing their attention as they read. For example.

Wilson (Ins): I look at the picture over here and look at the text under it to find out what it is, then I'll start reading after that.

Steve (Ind): After reading the words on 526, I look at the pictures at the top and the timeline on the bottom…After I finish reading 529, I go back through the entire section, reviewing the vocabulary.

Remark –random. In addition to noting where their attention was focused, 11 participants made a remark that did not relate directly to the topic of the text but demonstrated that they were paying attention to the text. These statements indicate that the participant did not understand the context in which the content was presented.

Chance (Ins): I'd be scared to get brain surgery.

Tina (Frus): This reminds me of that show where bugs go into the brain and eat it.

Chance (Ins): The term lysogenic makes me think of hand sanitizer for some reason.

Remark- text based. Remarks that were grounded in the content of the text were coded as text-based. These remarks differ from random remarks in that they demonstrate that the participant is engaged with the context in which the content was presented.

Monica (Ins): They always do experiments on mice.

Brad (Ins): That's awesome that they can inject dyes to make organs more visible without harming us.

Jake (Frus): It seriously looks like they're having babies.

Brad (Ins): There has to be something in modern medicine that can help stop the cycle.

Verbatim reading. Seven participants read a portion of text verbatim when reading the brain article and ten read verbatim with the viruses selection. Instructional level readers Kevin and Cindy, along with independent level readers Alana, read the most portions of text aloud from the brain article. Other participants such as independent level reader Whitney and instructional level readers Monica, Autumn, and John engaged in verbatim reading on three or fewer occurrences. When reading the viruses text, Amit (Ind) read verbatim on sixteen instances but did not read verbatim when reading the brain article. Only one frustration level reader, Tina, read verbatim and did so in the viruses text. Tina uttered two brief statements, "DNA enters the bacterial cell," and "the bacterial DNA becomes part of the bacterial chromosome."

Intratextual connections. Six participants made intratextual connections. In reading the brain article, three participants (2 Ins, 1 Ind) acknowledged connecting information from within the text in order to understand what they were reading.

> *Amit (Ind):* So maybe it sounds like the brain isn't connected to the bloodstream at all but only in the nervous system.

> *Lupe (Ins):* I know what it is now.

Predicting. Predictions using the material from the text were provided by six participants (5 Ins, 1 Ind) reading the brain article and six participants (3 Ins, 3 Ind) reading the viruses text. In many cases, the predictions were in regards to what they expected to see in the remaining text.

> *Stephanie (Ind):* Okay, so at the top I see this is about the brain. It kind of gives me an idea of what part of the body I'm looking at.

> *Francis (Ins):* I read the biggest text first because that leads me to believe that it's going to be like a thesis statement and it's going to help me remember and know what the paper's about…It's talking about animal trials which I guess leads me to believe that they haven't done any animal trials yet and they don't know that it will work on humans.

> *Rebecca (Ind):* So, I realize that this is going to be about the way a virus takes over the body and can't really be gotten rid of.

> *Brad (Ins):* It seems like there would be an easy way to stop it, you take one piece out and it stops the whole thing.

Questioning. Several participants verbalized a question that came to mind as they read. Questioning was utilized by ten (1 Frus, 4 Ins, 5 Ind) participants reading the brain article and six (1 Frus, 2 Ins, 3 Ind) participants reading the viruses text.

> *Whitney (Ind):* I wonder why it is that the brain lets through drugs or certain drugs through the barrier but not others? Does it do it automatically?

Jake (Frus): What does that mean? Is it talking about like where it would help the brain out?

Alana (Ind): How do they know it was smallpox? Couldn't it have been a similar disease?

Tina (Frus): Um, it leaves the new virus's host cell?

Deliberate efforts at comprehension. Strategies utilized that demonstrated a deliberate effort to understand the material were: memorizing, seeking clarification, describing, paraphrasing, and synthesis. As mentioned in the graphics section above, nine participants engaged in describing text or graphics when reading the brain article and fourteen engaged in description with the viruses selection.

Memorizing. One instructional level participant expressed an attempt to memorize information when reading both texts.

John (Ins): I read the definition twice because I see it must be something important, so I read it more than once to try to memorize it….I read the last sentence a couple of times because I didn't know it and I would like to, so I try to memorize it.

Seeking clarification/rereading. Participants demonstrated deliberate efforts to clarify understanding of the material through rereading and reasoning. Statements coded under clarification explicitly stated a need for further understanding either through a statement demonstrating a reasoning process or a question that they were seeking to answer within the text. Rereading statements specifically noted that the participant was reading or looking back at a section again but did not necessarily express the purpose for rereading.

Jake (Frus): Why's it inside the brain too? I guess it's legitly [sic] inside the brain too. I thought it was just around it, not inside it.

Brody (Ind): I'm looking at this picture of the blood vessel in the brain. Now that I've read a little bit, to get an idea of what it really looks like instead of what I'm thinking.

John (Ins): It confuses me, so I go back and read the first paragraph that discusses the blood-brain barrier.

Wilson (Ins): I didn't understand something, so I made sure to go back over that a couple of times to make sure I understood it.

Describing. Statements that told what the text or a graphic was about through a broad description were coded as *describing*. These descriptions did not involve higher level paraphrasing or synthesis as they did not demonstrate that the participant comprehended the information.

Kate (Frus): I read the first paragraph. Its talks about how they want to put drugs directly into the brain.

John (Ins): You've got somebody trying to figure out how you can "breakdown a rogue protein to bind a drug to a troublesome receptor."

Brody (Ind): I just read this larger part of the article and it was talking about how scientists are finding more about brain cancer, Alzheimer's, and Parkinson's.

Paraphrasing. Statements in which participants restated the text in their own words, demonstrating comprehension, were coded as *paraphrasing*. Fifteen participants paraphrased text when reading the brain article. Seventeen participants paraphrased the viruses selection.

Lindsay (Frus): I'm reading this part that scientists can see the body more clearly if they inject the tissues with dyes.

Jackie (Frus): The brain has a barrier that keeps toxins out, doctors didn't even know we had one until the 1900's.

*Lupe (In*s): They found out about the blood-brain barrier by injecting a dye into the nervous system and the brain turned blue. They concluded that there had to be invisible barrier… They tried it on a monkey and they got it through some small sections of the blood-brain barrier but then it was proved that within hours in the monkeys, their barriers had closed up.

Stephanie (Ind): Okay, so now scientists are trying to outsmart this blood-brain barrier because the need for people who are taking drugs at home they need to have some way that the brain is going to get better through that.

Amit (Ins): Okay, so I guess whenever you take medicine, it's put into your blood stream but this barrier type deal blocks it.

Stephanie (Ind): Then in the lysogenic cycle it actually inserts its DNA into the DNA of the host cell so it's not actually in the cytoplasm but it's not just there because I can see the pink part attaches to the blue and the as the host cell goes through a cell cycle it replicates it and then divides and spreads the virus.

Cindy (Ins): The influenza virus has an envelope, and the adenovirus has proteins in it.

Kevin (Ins): Viruses can't give you proteins, that's why they hurt your body.

Jackie (Frus): So, viruses harm then body because we're not getting protein and nutrients.

Synthesis. Nine participants made synthesis statements either connecting information gained from reading with prior knowledge to create new meaning or emphasizing new understanding gained from the brain article and twelve participants made such statements with the viruses selection.

Lindsay (Frus): I just finished reading the whole thing and what I'm thinking after that is that if the brain set the barrier up in the first place, it obviously didn't want certain things to get in.

Stephanie (Ind): Okay, that makes sense because the scientist decided that the barrier was more of a filter that it is a barrier and it seems to be intelligent…That may be another reason viruses aren't considered living because it says they have a host cell so anything that's living can live on its own.

Tina (Frus): It splits into two, so it's basically provirus formation but like two of them.

Summary of Qualitative Analysis

Participants utilized numerous processes throughout the think-aloud portion of the study. The majority of statements made by participants led to processes that emerged in analysis of the transcripts that involved using the texts' structure to organize and understand the content. Participants demonstrated two basic reading patterns based on the manner in which they attended to the texts' features and graphics. A few participants read the passages straight through without acknowledging the features. The majority of the participants allowed the vocabulary, headings, font changes, and use of color to direct their attention to certain portions of the text or graphics as they read. Various comprehension monitoring strategies were implemented by participants in order to make connections between the information presented in the text and graphics with prior knowledge. Comprehension monitoring strategies ranged in the degree of engagement demonstrated as some participants focused on general descriptions of the content while others worked to synthesize existing and new knowledge of the content.

In order to assess which processes were most commonly utilized in this study, the number of participants who used each process was tallied. Results were examined to identify the processes utilized by the majority, or at least half, of the participants. The processes utilized by the majority of participants (50%+) are summarized in Table 4.8.

Table 4.8

Most Utilized Processes

Codes/Processes
Graphic reference- specifies graphic by number, title, or content (84%)
Vocabulary (81%)
Navigates (78%)
Preview headings(75%)
Acknowledges familiar terms or content/Connect to Prior Learning (78%)
Describing (66%)
Recognition of unfamiliar material (56%)
Synthesis (53%)
Clarification (50%)
Skipping text or graphic (50%)

The most commonly utilized processes indicate that participants previewed headings and attended to graphics and vocabulary. Participants navigated their way through the text while describing the content. Participants also made choices to skip text or graphics. Efforts to clarify material were made in order to synthesize the material.

Differences In Process Use by Achievement Group

Transcripts were reviewed to determine which processes were most prevalent within each of the achievement groups. Processes that were utilized by at least half of the members of the achievement group in reading "The Brain" are summarized in Table 4.9 and results for the Viruses text are summarized in Table 4.10.

Table 4.9

ProcessesUtilized by 50+% of Each Group for "The Brain"

Frustration Level	Instructional Level	Independent Level
Acknowledges familiar terms or content (60%)	Preview headings (60%)	Acknowledges familiar terms or content (83%)
Graphic reference - reads caption (60%)	Recognition of unfamiliar material (53%)	Navigates (60%)
Remark- random (60%)		

Table 4.10

ProcessesUtilized by 50+% of Each Group for "Viruses"

Frustration Level	Instructional Level	Independent Level
Text structure - color or highlight (80%)	Vocabulary (67%	Navigates (92%)
Acknowledges familiar terms or content (60%)	Acknowledges familiar terms or content (60%)	Vocabulary (92%)
Order of reading - graphics first (60%)	Graphic reference- specifies graphic by number, title, or content (60%)	Graphic reference- specifies graphic by number, title, or content (83%)
Clarification (60%)	Preview headings (53%)	Acknowledges familiar terms or content (67%)
	Skipping text or graphic (53%)	Skipping text or graphic (67%)
		Clarification (58%)
		Rereading (58%)
		Preview headings (50%)
		Verbatim reading (50%)

The topic structure of the brain article differed from the viruses selection from the textbook in that it contained more continuous text as opposed to multiple headings, subheadings, margin vocabulary, and highlighted vocabulary. The processes most utilized in the brain article were fewer in number by comparison for all achievement groups.

Frustration level readers utilized the fewest number of processes when reading each text. In reading the brain article, the majority of frustration level readers utilized the graphic and made connections to familiar terms and content. They also made more remarks unrelated to the text. Frustration level readers reading the viruses selection navigated through the text by verbally indicating where they were looking as they read, often describing what they were reading or viewing. Independent level readers navigated as well during both texts but the majority of instructional level readers only did so during the viruses selection.

Instructional level readers focused more on unfamiliar material than making connections to familiar content when reading the brain article unlike the frustration and independent level readers. Although there was only one heading in the brain article, instructional level readers gave it more attention than frustration and independent level readers. The majority of instructional and frustration level readers focused on reading the caption that accompanied the lone graphic in the brain article. In reading the viruses selection, instructional level readers navigated their way through the text, focusing on familiar content including vocabulary as did the independent level readers. Instructional level readers also stopped to describe what they were reading or viewing in graphics.

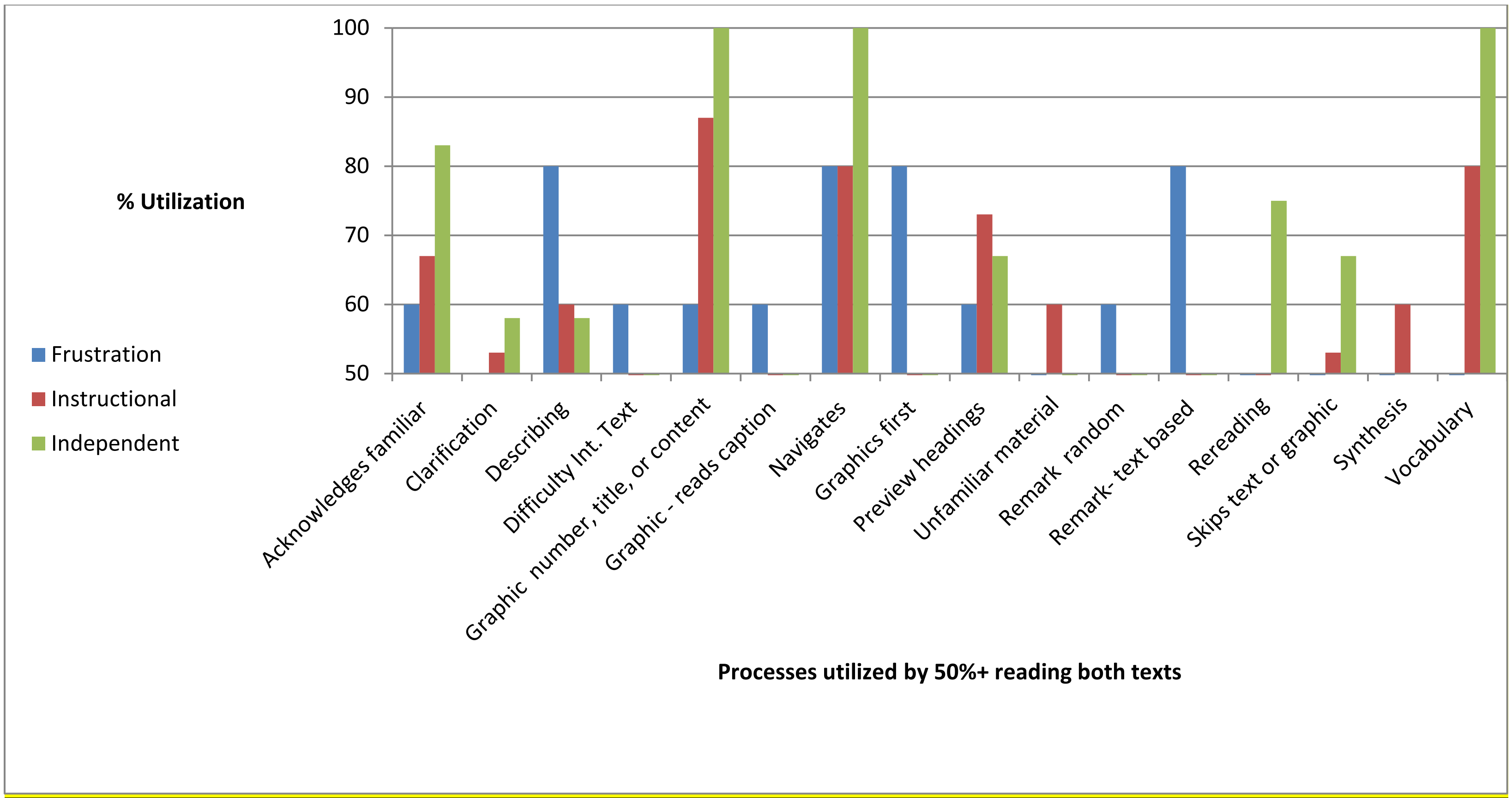
Instructional level participants were the only group to largely acknowledge that they viewed graphics when prompted within the text. Instructional level readers, like the frustration and independent level readers, frequently identified graphics by the number, title, or content. However, instructional level readers also noted skipping some text or graphics when reading the viruses selection, as did the independent level readers. Instructional and independent level readers spent time previewing headings with the viruses selection but the majority of frustration level readers did not mention the headings.

Independent level readers overall utilized only two processes when reading the brain article. The majority of instructional level readers navigated their way through the text, acknowledging familiar terms or content. In reading the viruses text, independent level readers utilized these processes along with previewing headings, identifying graphics, skipping text or graphics, and vocabulary. The previously mentioned processes were not unique to the independent level readers as the majority of frustration and independent level readers combined also utilized these processes. However, independent level readers utilized three processes that the other groups did not: clarification, rereading, and verbatim reading.

In order to examine the ability of participants to utilize each of the processes, transcripts were reviewed to determine whether a participant used a process at least one time during the think-aloud portion of the study. When considering the two reading selections together, the processes that emerged as most prevalent based on one use per participant are summarized in Figure 4.1.

Figure 4.1.

Processes Utilized At Least Once by 50+% of Participants Considering Both Texts



In order to compare the overall ability of participants to utilize processes, one time usage by participants during the think-aloud was considered. The processes utilized by at least half of the participants were as follows: acknowledges familiar terms or content; clarification; describing; graphic reference – specifies graphic by number, title or content; navigates; previews headings; recognition of unfamiliar material; skipping text or graphic; synthesis; and vocabulary. Four of these processes (acknowledges familiar terms or content , graphic reference – specifies graphic by number, title or content , navigates, and previews headings) were found to be utilized by the majority of each achievement group as well. The results for the instructional level were identical to the overall and the independent level included rereading as well. The largest differences existed between the overall results and the frustration level readers. Only the four aforementioned processes were common to both groups. The frustration level readers most utilized processes included five processes unique to this group: expresses difficulty interpreting text, graphic reference- reads caption, order of reading- graphics first, remark-random, and remark text based.

Oral Summary Results

Oral summaries were completed in order to inform the researcher on how well the processes utilized by participants aided their comprehension of the texts. The summaries also provided insight into how well participants utilized the topic structure of the texts. In order to develop a more complete understanding of the factors that may have affected a participant's comprehension and resulting summary, representatives from each achievement level are described using data collected from the questionnaire and their summaries for both texts are presented below. Summaries selected for inclusion in this section span the range of summary scores for each achievement group. Participants were asked to close the text and provide the summary from memory. Summaries were scored based on the following criteria in order to assess comprehension: 5 points were awarded for an overall main idea and one additional point was awarded for each correct supporting detail while one point was subtracted for incorrect details. The scores ranged from 2-13 for the viruses selection from the textbook and from 0-13 for *The Brain* (Zimmer, 2012). Table 4.11 provides a summary of scores by group and text.

After initial scoring of the summaries based on the content (presence of a main idea and the number of details provided by participants), a second scale was created to assess the quality of the summary. Many participants recalled the topics they read about, but others expanded on those topics and tied them together. Quality scores were awarded based on the following criteria: zero points for isolated details with no explanation; five points for details with explanations; ten points for details with explanations that were connected to form a coherent summary. Average summary scores with standard deviations based on content alone as well as content and quality scores combined are shown in Tables 4.11 and 4.12. Examples of summaries provided by representatives of each achievement group follow; summaries were marked to show how they were scored.

Table 4.11

Oral Summary Content Scores by Group and Text

	The Brain		Viruses	
Achievement level	Range	M (SD)	Range	M (SD)
Frustration (N=5)	1-7	4.4 (2.3)	3-10	5.2 (2.9)
Instructional (N=15)	1-13	6.9 (3.2)	4-13	7.1 (3.0)
Independent (N=12)	0-12	6.4 (4.0)	2-9	6.8 (1.9)

Table 4.12

Oral Summary Scores (Content and Quality Combined) by Group and Text

	The Brain		Viruses	
Achievement level	Range	M (SD)	Range	M (SD)
Frustration (N=5)	6-17	9.4 (4.5)	3-15	8.2 (4.6)
Instructional (N=15)	1-23	10.2 (6.2)	5-20	10.8 (4.4)
Independent (N=12)	0-22	10.2 (8.4)	5-17	10.2 (4.2)

In order to assess a general degree of comprehension when comparing participants' content summary scores, the range of scores for each text was broken down into the following categories, as shown in Table 4.13, using quartiles: participants scoring in the lower quartile, below the 25th percentile were considered to show low comprehension; average comprehension was associated with scores within the interquartile range; and high comprehension was associated with scores in the upper quartile, above the 75th percentile.

Table 4.13

Average Summary Scores and Comprehension Level.

		Comprehension Level		
Text	Scoring Method	Low	Average	High
Brain	Content	<4	4-9	>9
	Content+Quality	<5.75	5.75-15.5	>15.5
Viruses	Content	<5	5-8.25	>8.25
	Content + Quality	<6.75	6.75-13.25	>13.25

Frustration Level

Tina, Lindsay, and Kate were selected to represent the frustration level oral summaries.

Tina

Tina had the lowest score of all participants on the cloze (14). She reported that her favorite subject is art and her least favorite is math. In the questionnaire, she noted that she does not like to read and often stutters when reading aloud and gets distracted easily. When asked if she thinks she is a good reader she said yes and no, indicating the trouble reading aloud, but also noted that she is fine when she reads by herself. Tina reported reading only one or two books outside of school each year. Tina read the brain article straight through while mouthing or whispering the words to herself at a very rapid pace. Tina's summary was brief, providing only four details. Her summary indicated an average degree of comprehension of the article when compared to other participants. Tina expanded on the details provided and was able to communicate why scientists were trying to make holes in the barrier. Her combined content and quality score was nine.

Tina's summary of the brain.

> They were talking about how they were trying to color organs except for the brain and they changed some kind of organ to blue – I forgot what organ. *They were talking about breaking holes so they could get medicines and drugs through them*. This person discovered something about the brain about *getting the little hole to pass waves through the brain*, trying *to get drugs through* it so it can, like, the brain, *the blood brain barrier*. That's all I know.

In reading the viruses text, Tina attended briefly to graphics and provided some general navigation as to where she was looking as she read. Her pace was much slower than with the brain article. However, the processes she utilized were limited to navigating and referring to graphics by name or number. Tina demonstrated great difficulty interpreting the graphic of the lytic and lysogenic cycles during the think-aloud and that difficulty was reflected in the summary below which demonstrates a low level of comprehension. Tina was able to correctly communicate that stress can reactivate some viruses, her attempts to explain other statements were incoherent so she was given a quality score of zero for a total combined score of three.

Tina's Summary of Viruses

> The cycle has many cycles and the *STDs*. The STD was talking about *herpes* and *viruses that can come up and reactivate by stress*. That cycle was three sticks with worms in it. The worm thing has a rubber band in it, attaches itself to one that comes out and blends into part of the rubber

> band looking thing and then makes new ones and starts all over again. And basically about STDs and that's all I know.

Lindsay

Lindsay's cloze score of 31 was close to the remaining frustration level participants. She lists history as her favorite subject and math as her least favorite. Lindsay likes to read and considers herself to be a good reader. She reports reading three or four books outside of school but notes that she will stop reading if a book does not hold her attention. Lindsay was the frustration level reader who utilized the most processes while reading the brain article including acknowledging familiar content, paraphrasing, and synthesis statements. Although her summary of the article lacked an overarching main idea statement, she recalled seven details and explained the discovery of the blood-brain barrier and two ways to bypass the barrier. Lindsay was given a quality score of 10, giving her a combined score of 17, indicating an average to high level of comprehension overall.

Lindsay's summary of the brain.

> *There's [sic] these brain barriers, and on the picture they were outlined in green*. It's helping so things don't get into your brain like *there's this scientist that put a dye into, I believe it <u>was a dog</u>, so all his other organs turned the color of the dye. Another person put it in I think it was the nervous system and then nothing else turned the color of the dye except the brain and so it led them to believe that there were brain barriers set up*. Now they're trying to find ways to get through that barrier and *they're*

testing it on mice and monkeys to figure it out. *A couple of ways are like the antibodies, or whatever, and like they're trying to disguise the drugs antibodies like the Trojan horse effect*. And there, like, *ultrasound, they're trying to shake it I guess to loosen up the barrier to let the drugs in*. They're just trying to find an answer to all the neurological disorders and the mice and the monkeys worked very well with the ultrasound. *They were worried that human skulls were much thicker than mice, so they tested it on monkey's because they were afraid it would fry up all the tissue or whatever*. The monkeys did well, *they can still move their arms, they can see well and they're still sleeping so it has no like harsh effects on it that they can tell* but none of these things will be coming it doctor's offices anytime soon because there has to be so much more research and experiments before they can say it is safe to practiced and that the funding is limited.

In reading the viruses text, Lindsay utilized processes such as graphic references, clarification, personal connections and acknowledging familiar content. Lindsay correctly recalled six details. Despite two errors, she demonstrated average comprehension of how viruses work. Lindsay did not connect her explanations of the details offered together well, so she was given a quality score of five, for a combined score of 10, indicating an average level of comprehension overall.

Lindsay's Summary of Viruses

Viruses are very tiny strands or whatever and they're *not really sure if viruses are living thing because they don't have a lot of things*.. well there would be things they do have like organelles. They think they came from plant cells, no, sorry *they're from cells* and um they're tiny. *To be infected with a virus, it has to attach to a host cell* and *there's a capsid that surrounds the virus*. The *virus goes into the cell and spreads to the other cells and you have the flu or cold or whatever*. You *can't transfer viruses between species*.

Kate

Kate's cloze score placed her in the middle of the frustration level group. In reviewing data collected from the questionnaire, this student reported that her favorite subject is history while her least favorite is math. She reads 3 or 4 books per year outside of school and considered herself a good reader, "unless there's [sic] a lot of words that I don't know." With scientific text, there are many unfamiliar terms, which may explain the difficulty she had with comprehending both passages as exhibited in the lack of information provided during the think-aloud protocol and the summaries provided. Kate utilized only two processes when reading the brain article. She previewed the heading statement and contributed one text-based remark, "I read the first paragraph. It talks about how they want to put drugs directly into the brain – that sounds kind of painful to me." Kate's verbalizations ceased after the first paragraph. However, in her summary, Kate did make the effort to connect her thoughts despite a couple of mistakes, so she was given a quality score of five, for a combined score of 6, indicating a low to average level of comprehension overall.

Kate's Summary of The Brain

> *They were doing tests on the brain* and in *one of the tests, they put dye in one animal's body to see if it would color all the organs and all the organs were colored except the brain* and then they *did it to another brain and it turned it blue* and in *another one they put a saline solution with bubbles into a mouse* rather than to try to open the blood brain barrier or whatever that was called and *they did an* <u>ultrasound on a rat</u>*,* a mouse, they were just trying to figure out ways to treat the brain.

Kate's verbalizations during the viruses selection were limited to navigating and referencing graphics by their number or title. Kate was able to recall what she read about in that she provided five details. The summary below demonstrates an average comprehension of the text. However, Kate was given a quality score of zero because she merely mentioned the topics she read about and did not offer additional explanation. Kate's combined score was five. Overall, Kate demonstrated a low level of comprehension.

Kate's Summary of Viruses

> *It's about viruses*, what I read, and about on the first page its' *talking about STDs and childhood disease and just a bunch of different viruses that cause diseases*. It talks about *viral infections*. And the timeline talks about the *history of smallpox*. It's also talks about *the lytic cycle*.

Instructional Level

Autumn, Lupe, and Monica's summaries were selected to represent the instructional level.

Autumn

Autumn was one of the lower cloze scores in the instructional group. Her favorite subject was listed to be English, "because I like to read," and social studies was noted to be her least favorite, "because of the dates." She described herself as a good reader and reported reading approximately 50 books outside of school per year. In reading the brain article, Autumn offered little comment and utilized only a few processes including previewing the heading statement, recognizing unfamiliar material and reading the caption of the graphic. Autumn acknowledged a term she did not recognize by stating, "now, I'm looking at this word and I really cannot understand it. It's pharmaceutical." Autumn struggled with pronunciation of terms. Her comprehension of the brain article was rather low as she offered only one detail regarding the article which did not capture a full picture of the role of a neurologist. Autumn was able to recall what she read about in her summary. The content of her summary did not indicate the degree of understanding she had for the material as she made general statements regarding what she read. As Autumn offered only one isolated detail, her quality score was a zero and combined score was a one, indicating a low level of comprehension overall.

Autumn's summary of the brain.

> "In this article I learned that a *neutrologist[sic] are people that put medicine and things inside of the brain*."

As Autumn read the viruses text, she mostly navigated in that she indicated the heading for the section she was starting to read. She did indicate the number and name of the graphics and provided a brief description of the content of the graphic. Autumn's summary for this text demonstrates a higher degree of comprehension than did her summary of the brain article. In the summary below, she was able to provide an overarching main idea and five correct details. Despite difficulty with the terms "lytic and lysogenic," she was able to explain the details but did not tie them together, earning her a quality score of five and a combined score of 12. Overall, Autumn demonstrated an average level of comprehension.

Autumn's summary of viruses.

> **I just read about viruses and how they connect to a bacterial cell and what diseases can come from viruses**. I learned how the lystic *[sic]* and lysgenic *[sic]* cycles work and how they do cell division and everything *where they replicate the DNA and how it's released from the cell to do all the cell division*. I *saw in the pictures and the charts how the cell cycles works* and *where many of our diseases come from and many are from viruses.*

Lupe

Lupe's cloze scores placed him the middle of the instructional level group. This participant reported reading one book every two years outside of required school reading. He considered himself to be a good reader and enjoyed math and history, but not English class because, "we read boring books." Lupe's performance on the summaries was superior to the majority of instructional level participants. In reading the brain article, Lupe previewed the author and stopped to paraphrase three times. Lupe incorrectly referred to Alzheimer's and Parkinson's as type of brain cancers, but his comprehension overall was determined to be average to high based on his summary. He was able to provide an overarching main idea and five supporting details. He included one incorrect assumption regarding the effect of closing of the barrier after the ultrasound. Lupe explained how drugs get past the blood-brain barrier throughout his summary, supporting the main idea so he was given a quality score of ten and his combined score was 18.

Lupe's summary of the brain.

> Um, **the article was mainly talking about some drugs that they used to help heal body parts because the brain does not allow it to flow through, so it can't pass in your brain and go to all the parts of your body.** It only goes to certain parts.*The doctors were trying to find ways to open your blood brain barrier which is what doesn't allow most drugs to pass through*. They were just trying to figure out how they can get it to open up so that you could get your get the helping drugs in there. *They tried to use like a Trojan horse type of deal* and *one biomedical engineer used ultrasound by putting gas bubbles in your brain and using ultrasound to get small little holes in there and they figured out it worked on animals*, but one *they got to animals close to the human like monkeys they found it* <u>*closed up and didn't work*</u> and I *also read that it was very expensive and*

not very many people want to help fund this thing because it's not a conventional type of research.

Lupe utilized the following seven processes when reading during the think-aloud; unsupported or incorrect claim, acknowledges familiar terms or content, graphic reference- no identifying information, paraphrasing, preview headings, previews author, recognition of unfamiliar material. Lupe began the viruses selection by previewing headings and skimming the text. The majority of his verbalizations were connections to familiar or prior knowledge. The summary below includes mostly material that was stated to be prior knowledge in the think-aloud. Little new learning is demonstrated beyond the knowledge that the lytic cycle can be activated after a dormant period. Lupe's summary score for the viruses text was the third highest score among all participants. He was able to provide an overarching main idea and six supporting details. Lupe provided numerous details that he explained but he did not connect them to one another, so he was given a quality score of five, for a combined score of 16.

Lupe's summary of viruses

I just read about the types of viruses and how they get in your body and how that they can just stay in your body and just be dormant for a long time and they can just wake up and become active by the lytic cycle. And I also read that *most viruses are caused from outside things* and *that they can't move or they can't move or grow on their own,* they *have to be attached to a host cell*. And *most viruses are being eradicated by the discovery of new vaccinations* like *the smallpox vaccination was* *eradicated because they found a vaccine for it* and it talked about how different diseases are caused by different strands of the virus that people can catch.

Monica

Monica obtained one of the highest cloze scores in the instructional group. She reported reading approximately 3 books outside of school each year. Monica stated, "I only read when I have to and even then I look up Spark Notes. I don't have enough time." She did say that she feels she is a good reader, as she normally understands what she reads. Monica listed English as her favorite subject because, "it interoperates *[sic]* in many different ways, not just one meaning," and listed history as her least favorite because, "it's boring and it's too much to remember." In reading the brain article, Monica utilized processes such as acknowledging familiar and unfamiliar content including connections to prior learning, skimming for preview, text-based question, and synthesis. Monica's summary of the brain received the highest score of all participants. She provided an overarching main idea and provided eight supporting details indicating a high degree of comprehension. Monica tied the details of her summary to the main idea and explained how the blood-brain barrier was discovered as well as the methods tested to get medicines across the blood-brain barrier. Monica's summary was given a quality score of ten, giver her a combined score of 23.

Monica's summary of the brain.

In the brain there is a barrier that goes around the nerves in the brain. A guy name, *Paul E, he actually found the cure for syphilis*. He

> made this *dye they put in the brain to highlight different parts of it* which I think *must be the picture on the other side in green and red, showing the nerves in green and the barrier was red*. They knew the barrier was around it and they were trying to get different medicines and drugs through the barrier. *The barrier let certain things in and certain things it doesn't, its semi-permeable – that means it lets some stuff in and not others*. They *were testing ultraviolet sound on rats and they tried it on monkeys* but the *barrier only stays open for a certain amount of time*. Like *it didn't stay open, it only stayed open for a couple of hours*. I remembered a lot more from this one than I did the other one. Probably because, I don't know, this one seemed like a documentary of someone actually doing the studies and stuff. Oh, and the insulin - *the brain was letting insulin through so they were going to try to put it on the insulin to get it through then on antibodies from there*.

Monica's reading of the viruses text involved processes such as viewing graphics when prompted within the text, acknowledging familiar and unfamiliar content including connections to prior learning and personal connections, expression of difficulty with text and graphic, and skimming for preview and review. Monica's summary of the viruses was much weaker than her summary of the brain article. Monica explained how viruses reproduce but did not explain other details such as the lytic and lysogenic cycles, so she was given a quality score of five, resulting in a combined score of 10. .Based on her summary, Monica was determined to have an average level of comprehension.

Monica's summary of viruses.

> I know that *viruses come in different shapes and sizes* but *they're really, really small* though. *They cannot reproduce on their own* but *they attach to cells and they put their DNA in those cells then the cells replicate* so it's like piggybacking on the cells and they do work for them. *There's two cycles that both start with "L", [tries to pronounce 'lytic' and 'lysogenic'],* those two cycles. That's about all I don't remember much. Usually I have to read stuff 2 or 3 times, especially in science and history.

Independent Level

Alana, James, and Stephanie were selected to represent the independent level.

Alana

Alana scored in the lower half of the independent level readers on the cloze. Her favorite subjects were reported to be German and math while science was listed as her least favorite. She reported that she enjoys reading and reads 60 books per year. Alana noted that she is a good reader unless the reading is for school which she finds boring. In reading the brain article, Alana utilized numerous processes, including: acknowledging familiar content through connections to prior learning, synthesis, text based remarks and questions, rereading, reading verbatim, and navigating. Alana's summary of the brain received the second highest score among all participants based on her summary statement and details provided. Her summary included an overarching main idea and seven supporting details, indicating a high degree of comprehension. Alana was able to connect the details and facts she recalled in order to support the main idea, so she was give an additional quality score of ten for a total combined score of 22.

Alana's summary of the brain.

> **This article was talking about trying treat diseases like Alzheimer's and things by drilling a hole through your head, kind of**. Because *there's a barrier surrounding your brain full of fatty things* and *because of that barrier you can't if you give like pills or something, sometimes the medicine can't make it through*. Researchers are *trying to find a way to get medicines through*. Basically *it's kind of like a cell that filters out like everything that it doesn't need.* So they *tried attaching various drugs to things that are allowed past the barrier and then that kind of worked*, I guess. Then some people tried making drugs what you needed, I guess. The a woman who has a really hard name that starts with a "K" decided that if she has like a lot of little, *tiny vibrations, I think, they'll make like a hole through your brain so that way you can get the things you need through it.* With this she *tested it on monkeys and mice and it did work and there were no side effects*. But it's really expensive and kind of unethical for people and so a lot of people are against it, I guess.

In reading the viruses text, Alana engaged the same processes as she did when reading the brain article in addition to a numerical reference and an expression of difficulty interpreting a graphic. While viewing the graphic of the lytic and lysogenic cycles, she stated, "still looking at the chart because it's kind of concerning. Apparently, every cell can, like, every virus cell I guess, can make like itself again plus two others. So, I guess that's why a virus spreads so easily." Her summary includes an overarching main idea and four supporting details; however, Alana did not connect the details and did not expand on them. Instead, she merely stated what she read about, earning her a quality score of zero, for a combined score of 9. Based on her summary, Alana's comprehension level of the viruses text was found to be average to high.

Alana's Summary of viruses.

> **Okay, so this chapter is about viruses and how they spread quickly, how they reproduce and infect germs or other cells**. And there's two different cycles, *the lytic* and another one that begins with an "L" that's pretty complicated. *There's different types of viruses like smallpox, aids, and herpes* and things. It gives a *quick summary of smallpox and where it started.* The chapter also talks about *how, I guess, cells or viruses begin*.

James

James scored in the middle of the independent level group on the cloze. James listed his favorite subject as biology because, "I love it and it entertains me," and his least favorite as physics because, "I find no attraction or desire for it." He reported that he likes to read in his free time, and he reads between five and ten books per year. In reading the brain article, James utilized only a few processes including, previewing the author, acknowledging familiar content through a connection to prior learning, graphic reference, and two general remarks that did not specifically relate to the content of the text. Despite being placed in the independent level, James's summary score was a zero as he did not relay any specific information related to the topic of the article. As there were no details cited, James received a quality score of zero. He cited boredom with the topic as the reason for not understanding what he read. If James's score were removed, the independent level group's average content score would have been 7.0 and the combined content and quality average score would have been 11.1, which would have placed the independent level average scores just above the instructional level. However, since the goal of this study was to understand how students read scientific text, the lack of data James was able to recall provides valuable information.

James's summary of the brain.

> The only thing I got out of it was the division of the brain. Um it, it really doesn't excite me at all. I really can't tell you what I just read.

In reading the viruses text, James utilized more processes than with the brain article. He navigated to indicate where his attention was focused, paraphrased, described the lytic and lysogenic cycles, and made several text-based remarks. James's summary did not include an overarching main idea but did offer eight details which he explained, earning him a quality score of five and combined score of 13. James's comprehension of the viruses text was determined to be average.

James's summary of viruses.

> What I just read was about viruses, which, like I said reminds me of now because I'm sick. I just read about how viruses, what viruses are and how *some scientists don't think they're life forms* but *they have DNA* which I personally think is pretty cool that they can navigate and the *diagram*

showed the history of smallpox which has lasted for thousands of years until we just found a cure. I won't say a cure, um, I don't know the word for it. I read about what I have, I don't know the name of the cell or bacteria off the top of my head, I' m sure if I thought about it long enough I'd eventually remember it. I also read about *how viruses latch onto host cells*, which *is the lytic cycle* where *it goes into it and replicates itself*. Then, I learned about the *lysogenic cycle* where *it goes in and it stays in there permanently*, which is quite scary but that's what happens.

Stephanie

Stephanie's cloze score was the highest of all participants. She reported reading 40-50 books per year, mostly fantasy and romance novels. She notes that she can easily identify words that she doesn't know when reading. Her favorite subjects are music and band because she says she "can freely express herself as an artist." Stephanie noted that she does not like math because, "I make easy mistakes."

During the think-aloud protocol, Stephanie paraphrased and related content to prior knowledge. In total, Stephanie utilized the following processes as she read the brain article: acknowledges familiar terms or content, graphic reference - reads caption, paraphrasing, predicting, synthesis, and unsupported or incorrect claim. Stephanie's summary of the brain article demonstrates a high degree of comprehension in that she was able to provide an overarching main idea along with five supporting details. Stephanie was awarded a quality score of ten, since she was able to connect her details to support the main idea. Stephanie's combined score was 20.

Stephanie's summary of the brain.

> **It started out talking about how the brain has a skull but with different diseases they might need certain drugs or whatever to get to the brain itself and then they discovered that it has this barrier that actually could bring things in to the brain that it needed and it could bring other things down that it didn't need**. And so these, from the picture I could tell *these cells have kind of membranes around them sort of that kind of link together* so then *they were using different tests but there was one that had an ultrasound and it sent waves through the brain that loosened up the cells to get the drugs through*. Then *they tried to camouflage the drugs and put them into the brain but even though those two things seem to be working that they haven't really tested them on humans*. They *did test on mice and then I know they did one on monkeys* so then *they're just trying to figure out how this could work and it will be a while before anyone can see this in humans*.

When reading the viruses text, Stephanie utilized the following eleven processes as she read: acknowledges familiar terms or content, clarification, graphic reference - reads caption, navigates, numerical reference, paraphrasing, predicting, preview headings, skipping text or graphic, synthesis, and vocabulary. Unlike the majority of participants, Stephanie not only looked at the graphics, she interpreted the information contained in the graphic. In her summary, Stephanie did not provide an overarching main idea but was able to provide and explain seven details which she connected, giving her a quality score of ten and s combined score of 17. Stephanie demonstrated a high level of comprehension.

Stephanie's Summary of Viruses

> Okay, so the *virus is considered nonliving because it doesn't have any organelles* but the way that it works*, it hooks onto a host cell and kind of bosses it around*. It *tells it to duplicate its own chromosomes whether that be in the cytoplasm or in the nucleus*. And then, um, it fills itself up and then goes throughout the body like *if you're exposed to it, like say if someone around you has the flu, then the symptoms could show maybe three or four days later it shows how immediate it is* and then *the viruses were always known about as in ancient times they had different names for them than we do now but as technology got better we learned more about it*. And then the *two cycles that it replicates in are the lytic* and *lysogenic.*

Strategic Content Literacy Assessment (SCLA)

The SCLA was included to provide triangulation of the data collected in the think-aloud protocol. A rubric adapted from Alvermann, Gillis, and Phelps (2013) was used to evaluate the SCLA. Each question was scored on a scale of 0 to 5 and each question was identified with the reading process it addressed. Question one addressed connection to prior knowledge, questions two and six addressed summarization skill, question three assessed inferencing skill, question four assessed knowledge of content vocabulary, and question five assessed metacognitive skill. The average score and standard deviation for each question on the SCLA were calculated by achievement group and are presented in Table 4.14.

Table 4.14.

Group SCLA Score Averages by Question

	Average Score by Achievement Group		
Question No. (Skill assessed)	Frustration Mean (SD)	Instructional Mean (SD)	Independent Mean (SD)
Q 1 (prior knowledge)	1.4 (.89)	2.2 (1.2)	3.2 (1.3)
Q2 (summarization)	3.4 (1.7)	2.7 (1.5)	3.2 (1.5)
Q3 (inferencing)	2.8 (2.2)	3.1 (1.8)	3.0 (1.5)
Q4 (vocabulary)	2.2 (.45)	2.5 (1.1)	3.2 (1.3)
Q5 (metacognition)	3.0 (.71)	2.9 (.88)	3.7 (1.4)
Q6 (summarization)	2.4 (1.8)	2.5 (1.6)	3.3 (1.3)

Prior Knowledge

Question one addressed skill with prior knowledge. For the passage, frustration level readers had the lowest average score (M=1.4, SD=.89) on this measure and independent level readers scored the highest (M=2.2, SD=1.2), with the instructional level readers' average score in the middle (Mean=3.2, SD=1.3). As performance on the cloze assessment is affected by prior knowledge of subject matter and the fact that the topics were related, it was not unexpected for the scores on this measure to fall as they did. However, during the think-aloud the majority of participants utilized prior knowledge including the majority of frustration level participants.

Summarization

Questions two and six of the SCLA assessed participants' skill with summarization. Question two allowed participants to choose the mode of representation they preferred to use in order to summarize main ideas while question six specifically requested a diagram of the prokaryotic cell. Frustration level readers scored higher (M=3.4, SD=1.7) than instructional (M=2.7, SD=1.5) and independent level (M=3.2, SD=1.5) readers on question two which allowed them to use a diagram, concept map, or summary to communicate the important ideas. Four frustration level readers elected to write a summary and one drew a diagram. However, frustration level readers scored the lowest on question six which required participants to draw and label a diagram. Frustration (M=2.4, SD=1.8) and instructional level (M=2.5, SD=1.6) readers' average scores on question six were within .10 points of one another. Independent level (M=3.3, SD=1.3) readers scored one point higher on average than the frustration and instructional level.

Average summary scores of the frustration and independent level readers were more similar in the SCLA, whereas the instructional level readers were more similar to the independent level in the oral summaries following the think-aloud. The summary questions of the SCLA were answered with access to the passage while the passages were not accessible during the oral summaries. The passages read during the think-aloud protocol were longer and addressed two different topics. Several instructional level readers utilized a variety of processes and verbalized thoughts more than some independent level readers. The degree of interaction the independent level readers had through comprehension strategies utilized may explain the differences in summary scores on the oral summary versus the SCLA. When the text was available, the independent level readers did not have to work as hard to remember the material which meant they may not have made as many connections with prior knowledge in the SCLA text.

Inferencing

Question three of the SCLA assessed participants' skill in making inferences from the text. All three achievement groups' average scores were very close on this question which asked for a statement relating prokaryotic and eukaryotic cells. The instructional level (M=3.1, SD=1.8) performed slightly better than the frustration (M=2.8, SD=2.2) and independent level (M=3.0, SD=1.5) During the think-aloud protocol, very few readers made inferences from the text. However, the material in the SCLA was more familiar to participants since they would have studied eukaryotic cells in middle school. In this instance, the SCLA predicted that participants had facility with a skill that was not demonstrated in the think-aloud.

Vocabulary

Question four of the SCLA assessed participants' skill with content vocabulary. Frustration level (M=2.2, SD=0.45) and instructional level (M=2.5, SD=1.1) readers' average scores on this measure were similar. Independent level (M=3.2, SD=1.3) readers obtained the highest average score which once again can be attributed to a higher degree of prior knowledge. During the think-aloud, 40% of frustration level readers, 67% of instructional, and 100% of the independent level readers verbalized attention on vocabulary. Participants were aware that they would be providing a summary at the end of the think-aloud protocol for each text, suggesting the instructional and independent level readers understand the value of vocabulary in comprehending text.

Metacognition

Question five addressed metacognition. Participants indicated whether the task was easy or hard and were asked to provide support for their answer. The frustration (M=3.0, SD=0.71) and instructional level (M=2.9, SD=0.88) readers were similar in their performance on this measure. The independent level (M=3.7, SD=1.4) readers were more adept at explaining why they found the task easy or hard. The ability to utilize processes and select strategies to help one understand text indicates that a reader has metacognitive skill. During the think-aloud instructional level readers utilized similar processes as the independent level such as expressing difficulty with text, rereading, clarification, and recognition of unfamiliar content.

Triangulating the Data

For the purposes of triangulation, the codes that emerged during the think-aloud were compared with the processes examined in the SCLA: inferencing, metacognition, prior knowledge, summarization, and vocabulary. The processes of the SCLA were matched with codes in Table 4.15.

Table 4.15

SCLA Processes and Corresponding Think-aloud Codes

SCLA	Think-aloud
Inferencing	Predicting
Metacognition	Difficulty with text/graphic
Metacognition	Recognizes unfamiliar
Metacognition	Seeking clarification
Prior Knowledge	Acknowledges familiar
Prior Knowledge	Personal connections
Summarization	Paraphrasing
Summarization	Synthesis
Vocabulary	Vocabulary

In addition to the codes that support the SCLA processes, codes emerged for processes that provide a wider view of how participants approached the texts. The codes that were discovered through analysis in addition to those examined in the SCLA are summarized in Table 4.16.

Table 4.16

Think-aloud Processes in Addition to SCLA Processes

Think-aloud Codes		
Break in pattern	Number, title, content	Skims for preview
Color or Highlight	Numerical reference	Skims for review
Describing	Previews author	Skims graphic
Font	Previews headings	Skips graphic
Graphics first	Questioning	Skips text or graphic
Intratextual connection	Reads caption	Unsupported/incorrect claim
Memorizing	Reads straight through	Verbatim reading
Moves text graphic	Remark-random	Views after prompt
Navigating	Remark-text based	
No identifying information		

Summary

One goal of the present study was to determine the processes participants were using when reading scientific text. After analyzing the transcripts from the think-aloud portion of the study, the most frequently utilized processes by the participants as a whole were found to relate to text structure, prior knowledge, reading pattern, and comprehension strategies.

The second goal of the study was to examine the differences between the processes utilized most by frustration, instructional, and independent level readers. The strategies utilized by at least half the participants of each achievement group were identified and comparisons were made across groups and texts.

In order to understand how effective the processes utilized by participants were in comprehending the texts, oral summaries were recorded at the end of each think-aloud protocol. Scores on the summaries gave an indication of how well participants were able to use the structure of the text. Summaries were evaluated based on content and quality. Comprehension level was determined calculating the interquartile range.

Results for the SCLA were presented by question for each group. These data indicated what processes participants were expected to be able to use. These processes were examined against the processes that emerged during the think-aloud for triangulation purposes. Chapter 5 will examine the differences in group performances during the think-aloud as well as the differences in processes participants were expected to be able to use according to the SCLA and the actual processes utilized.

CHAPTER FIVE

DISCUSSION

This chapter presents a brief summary of the study followed by an interpretation of results presented in the previous chapter, limitations on the generalization of the results, recommendations for instruction, and implications for future research.

Summary of the Study

Situated cognition is a learning theory that describes the path from novice to expert as a learning trajectory and supports the idea that students need to be provided experiences that move them toward expertise (Brown, Collins, & Duguid, 1989). In thinking about where to begin in order to move students toward expertise with disciplinary literacy, the focus of this study turned to the development of the following research questions:

1. What processes and cognitive skills do students use when reading scientific text?
2. How do students of varied achievement levels differ in their reading of scientific text?

To answer these questions, grounded theory techniques (Creswell, 2007; Glaser & Strauss, 1967; Strauss & Corbin, 1990) were selected in order to capture processes as they were utilized when reading. A think-aloud protocol (Ericsson & Simon, 1993) was selected as the main instrument for gathering information on the processes students use when reading scientific text. A SCLA (Alvermann et al, 2013) was used to triangulate the data collected in the think-aloud

A sample of 32 students was drawn from volunteers from science classes at the test site. Participants were between 15 and 18 years old and represented the 10th, 11th, and 12th grades. A cloze assessment was selected to divide the participants into achievement groups as it has been shown to be effective in assessing the interaction of prior knowledge and text structure, two concepts affecting comprehension (Greene, 2001; Ridgeway, 1994).

Participants read two passages of scientific text while thinking aloud. Each passage was followed by an oral summary. In order to obtain the most accurate information regarding the processes students use when left to their own devices, no prompting occurred during the think-aloud or summary portions of the data collection (Priede & Farrall, 2011; Fox et al., 2011).

Transcripts were coded using the constant comparison method (Glaser & Strauss, 1967) in order to ascertain the processes used by students across the sample. Think-aloud data showed that the majority of participants focused comments on elements of text structure, prior knowledge, reading pattern, and comprehension monitoring strategies. Processes were also examined to determine differences between processes utilized by the three achievement groups.

Processes Utilized While Reading

The first concern of this study was to understand what processes high school students use while reading scientific text. With few studies in the literature on this specific population, there was a need to understand where students stand on the learning trajectory between novice and expert (Brown, Collins, & Duguid, 1989). The new

Common Core Standards for Science and Technical Subjects (NGA, 2010b) were designed to scaffold students along the path toward expertise in reading scientific texts. The studies available in the literature focused mostly on experts and high achieving students. The goal of this study was to understand how a sample of high school students representing all achievement levels read selections of scientific text. This information will provide educators a foundation on which to build disciplinary appropriate skills.

The analysis of the think-aloud transcripts and oral summaries revealed the following:

- Processes utilized by participants focused on text structure, prior knowledge, reading pattern, and comprehension strategies.
- Vocabulary references were less frequent when vocabulary was not highlighted or bolded.
- Few participants relied on the graphics to clarify meaning of the text.
- Participants utilized a larger variety of processes when reading the textbook selection on viruses than with the text on the brain.
- Comprehension, as measured by oral summary averages, was higher for the viruses selection.
- Comprehension ability varies from one text to another.

Think-aloud Data

The think-aloud portion of the study revealed ten processes that were utilized by at least half of the participants overall: (i) acknowledges familiar terms or content; (ii) clarification; (iii) describing; (iv) graphic reference (specifies graphic by number, title, or content), (v) navigates; (vi) preview heading; (vii) recognition of unfamiliar material; (viii) skipping text or graphic; (ix) synthesis; and (x) vocabulary. Each of these processes fell under a grouping that encompassed other processes with a similar purpose.

Text structure. References to content vocabulary and references to graphics that included identifiers such as number, title, or content were grouped under text structure. These processes demonstrated that participants were attending to features of the text designed to convey information through visual cues (Lorch, 1989). Vocabulary references were generally made for terms that were highlighted, bolded, or part of a list in the margin of the text. The usage of both vocabulary and graphics to creadte meaning and subsequent summary of the text is supported by Mayer's Theory of Mulitmedia Learning (2005).

Color, font changes, and highlighting were used extensively in the textbook selection and were noted in the think-aloud. Such features of text have been noted to be useful as cues to direct readers' attention to information the author deemed important in order to understand the macrostructure (Lorch, 1989; Mayer 2005). Color and highlighting were effectively used in the viruses textbook selection, as vocabulary that were in bold text were noted more frequently in the think-aloud. Focusing attention on vocabulary, a shifting strategy found in good readers (Israel, 2008), provided readers with an opportunity to read the vocabulary in the margins in order to clarify meaning. Vocabulary references were less frequent in the brain article because it did not specifically feature content vocabulary through font changes or lists, indicating that participants were sensitive to this feature of text.

The inclusion of graphics in text has been found to lead to greater reading comprehension (Schnotz & Bannert, 2003; Mayer, 2005). The degree to which a graphic can enhance comprehension is dependent upon how readers interact with the graphic. The majority of participants referenced one or more graphics during the think-aloud through identifying the number, title, or content. Many readers were prompted to view visuals by signals within the text (Lorch & Lorch, 1996), again demonstrating a response to the text's structure. The level of interaction with graphics varied from skimming to moving between text and graphic, in order to increase comprehension through a dual coding process (Clark & Paivio, 1991). The majority of participants did not discuss the content of graphics. Instead, they simply identified the content with no evidence of comprehension. Few participants relied on the content of the graphics to clarify meaning. However, those that did focus on the graphic of the lytic and lysogenic cycles, for example, demonstrated greater comprehension of viral replication. Mayer's (2005) theory of multimedia learning supports the notion that the ability of readers to select relevant information from a graphic is a key in the graphic's role in increasing comprehension, as the information will support the formation of a flexible schema. Studies of experts reading showed that scientists relied heavily on graphics for information, knowing that graphics may contain information not contained in the text (Shanahan & Shanahan, 2008b; Shanahan et al., 2011). The participants in this study did not make this connection, but their referencing of graphics indicates they understand that graphics are not to be ignored, which is a move in the right direction. With increased background knowledge and opportunities to practice using graphics to gain information, participants have the opportunity to develop disciplinary appropriate skills

Participants' use of such strategies and processes demonstrated that participants were responding to the text's structure and were able to implement shifting strategies as they monitored their comprehension (Israel, 2008); in other words, these participants demonstrated a degree of cognitive flexibility (Parris & Block, 2008). Participants reading *The Brain* (Zimmer, 2011) utilized fewer processes overall when compared to the processes utilized in reading the selection from the textbook on viruses. The texts differed in features such as bold heading and subheadings, as well as vocabulary lists. The brain article offered one visual in comparison to multiple visuals in the textbook selection. The textbook selection offered more cues or signals to guide readers to important information through the use of headings and bolded vocabulary terms which may explain the difference in the number strategies utilized with each text (Lorch, 1989).

Prior knowledge. Prior domain knowledge has been found to play a large role in comprehension of text in that it allows readers to make connections with new material encountered in the text (Cromley, Snyder-Hogan, & Luciw-Dubas, 2010; Ozuru, Dempsey, & McNamara, 2009; Samuelsteun & Braten, 2005). According to schema theory (Anderson & Pearson, 1984) when readers encounter new information, they attempt to fit it in with existing schema. A reader's ability to assimilate new information with existing schema is dependent upon how well that schema is developed (Anderson & Pearson, 1984; Ausubel, 1964). Participant comments regarding prior knowledge involved statements acknowledging familiar material, as well as unfamiliar material.

Verbalization of whether or not material was familiar indicated that participants were accessing long-term memory in order to make sense of the new information (Anderson & Pearson, 1984). Participants making connections between personal experiences and the information presented were also attempting to assimilate the new information with existing schema (Anderson & Pearson, 1984; Ausubel, 1964). The skill demonstrated by participants indicates that participants were making decisions regarding which information was not important for them to read. Experts demonstrate a similar process when reading in that they skim the text and focus most of their attention on new material (Shanahan & Shanahan, 2008b; Shanahan et al., 2011).

Reading pattern. Knowledge of the text structure affected the manner in which participants read the texts. Two processes grouped under reading pattern that were utilized by at least half of the participants were *previews headings* and *skips text or graphic*. Pressley and Afflerbach (1995), in summarizing a number of studies, noted that good readers engage in pre-reading strategies such as overviewing and identifying information that they feel is important and information they plan to ignore.

The ability to utilize text structure was evident in the manner in which participants read the passages. Features of the text such as color and font changes served as signals to the reader that material was important which prompted many readers where to read next (Lorch, 1989; Lorch & Lorch, 1996). Headings and subheadings played a large role in the reading pattern followed by participants. Previewing the headings provided readers a preview of the reading passage and provided an overview of the organizational structure of the passage (Lorch, 1989; Sanchez, Lorch, Lorch, Ritchey, McGovern, & Coleman, 2001). The majority of participants did not read the passage straight through, instead they followed the signals and prompts within the text indicating they were attentive to text structure. For example, participants moved from the body text to margin vocabulary or graphics and noted headings and subheadings as they encountered in the text.

Several participants in the study noted that some of the graphics in the viruses selection, such as the smallpox timeline, were not important so they skipped them. Good readers often skip text and graphics they determine are unimportant (Israel, 2008; Pressley & Lundberg, 2008), but in the case of novice learners, skipping text may indicate a lack of understanding.

Comprehension monitoring strategies. The majority of participants engaged in four processes grouped under comprehension monitoring strategies: (i) navigating; (ii) seeking clarification; (iii) describing; and (iv) synthesis.

The most frequently utilized process of all in the think aloud was navigating. Participants verbalized where they were looking as they read. They noted the sections, heading titles, and graphics. This allowed participants to interact with the text both visually and verbally, but did not indicate comprehension.

Participants sought clarification through questioning or rereading. Participants focused most of their efforts on understanding vocabulary. Clarification of vocabulary decreases a loss of interest in reading and leads to greater comprehension (Mikk & Kukemelk, 2010). Participants overlooked a rich source of information since they rarely consulted the information contained in the graphics to clarify meaning. Clarification strategies were not utilized frequently by a large percentage of participants, indicating that high school students may become frustrated and lose interest in reading scientific text if the content or vocabulary becomes too difficult.

Description of content in text or graphics was a process also utilized by the majority of participants and ranked high in frequency of use as well. This process did not involve a demonstration of comprehension directly, but indicated that participants were interacting with the content and were making an attempt to understand.

Synthesis statements were contributed by the majority of participants. Synthesis statements demonstrated comprehension; participants were able to connect pre-existing and new information in order to create meaning from the text. Since students are attending to information, as evidenced by their descriptions, steps to move these descriptions toward synthesizing information should be taken.

Comprehension monitoring strategies not utilized by the majority of participants, but that were used most frequently in the think-aloud included paraphrasing and verbatim reading. Participants engaged comprehension strategies such as paraphrasing, reading aloud verbatim, synthesizing information within the text, description of material in the text or graphics, questioning. Paraphrasing is often accomplished before learning to effectively summarize text, which supports the summary data collected since instructional level readers paraphrased the most and produced the strongest summaries (Kletzien,1998). Reading aloud verbatim allows the reader to see and hear the text, providing two modes for coding the information (Clark & Paivio, 1991). These skills also provide a foundation on which to build deeper level processes such as synthesizing.

These strategies have been shown to increase comprehension and contribute to better recall as they serve to integrate information with existing schema (Anderson & Pearson, 1984; Mayer, 2005; Shanahan & Shanahan, 2008a) and to provide multiple ways of processing the text (Clark & Paivio, 1991). However, less than half of the participants engaged in some or all of these strategies or processes, indicating that there are many students in high school classrooms who either lack the knowledge of or ability to utilize such strategies and processes when reading

Summary of Processes Utilized by All Participants

Participants' use of the strategies and processes in this study demonstrated that participants were responding to the text's structure and were able to implement shifting strategies as they monitored their comprehension (Israel, 2008); in other words, these participants demonstrated a degree of cognitive flexibility (Parris & Block, 2008). Participants reading *The Brain* (Zimmer, 2011) utilized fewer processes overall when compared to the processes utilized in reading the selection from the textbook on viruses. The texts differed in features such as bold heading and subheadings, as well as vocabulary lists. The brain article offered one visual in comparison to multiple visuals in the textbook selection. The textbook selection offered more cues or signals to guide readers to important information through the use of headings and bolded vocabulary terms which may explain the difference in the number strategies utilized with each text (Lorch, 1989). In order to facilitate students' ability to more effectively use the processes and strategies presented in this section, students need to be given opportunities to read a variety of text styles.

Oral Summary Data

The effectiveness of the processes utilized was measured through oral summaries of the texts read in the think-aloud. The data were summarized based on the content recalled, as well as on the quality of the summary.

The differences in the structure and length of the texts and the text structure affected how participants responded during the think-aloud, as well as the content and quality of the summaries. Participants engaged in using fewer processes when reading the brain article in comparison to the textbook passage. This difference suggests that this genre is less familiar and that participants were not able to transfer processes they demonstrated knowledge of to their reading of this text. The content score for the average of all summaries of viruses was above that of the brain article. The average content and quality combined scores for the viruses text was also higher than that for the brain article. The level of comprehension was not consistent across texts, suggesting that familiarity with the particular structure of a structure affects comprehension (Meyer et al., 1991). However, participants who reported being avid readers outside of school performed better on the summary of the brain article than on the textbook selection. The structure of the text in the brain article was more similar to that of a novel when compared to the textbook passage in that it was not filled with headings, subheadings, and font or color changes. For students who normally read novels, the cues provided throughout the textbook selection may have created more of a distraction.

Differences in Processes Utilized by Achievement Groups

The second goal of this study was to understand what differences may exist between the processes utilized by the three achievement levels. With respect to this question, the following differences came to the forefront:

- Independent level readers spent more time previewing and reviewing vocabulary.
- Frustration level readers made fewer statements overall.
- Frustration level readers engaged in fewer pre-reading strategies.
- Instructional level readers focused more on unfamiliar material when reading the brain article than the frustration and independent level readers who focused more on familiar material.
- Instructional level readers followed prompts to vocabulary and graphics.
- The instructional level readers outperformed the independent level on oral summary content scores and the combined quality and content score for viruses.
- The frustration level readers scored higher on their summaries of the brain than viruses for the combined content and quality scores unlike the instructional and independent groups.
- Frustration level readers demonstrated a lower level of comprehension on summaries than instructional and independent level groups.
- Reading preference and interest appear to affect processes utilized and resulting comprehension scores for some participants.

- Independent level readers focused more on unfamiliar material than the frustration and instructional level readers who focused more on familiar material.

Text Structure

Dual coding theory supports the use of visual and verbal representations to facilitate formation of appropriate schema which is facilitated for lower achieving readers when graphics are available (Clark & Paivio, 1991).The three achievement groups' abilities to use text structure effectively, in order to comprehend strategies, varied with the degree of prior knowledge of scientific text structure they possessed. Lower achieving readers often lack knowledge of text structure, so the cues provided are often ineffective with this group (Lorch, Lorch, Ritchey, McGovern, & Coleman, 2001; Meyer, Brandt, & Bluth, 1980). A lack of knowledge of text structure inhibits the type of processing and resulting mental model that can be created thus affecting the ability to remember and apply knowledge contained in text (Anderson & Pearson, 1984; Clark & Paivio, 1991; Wolfe & Woodwyk, 2010). In the current study, many frustration and instructional level readers demonstrated a lack of knowledge of text structure in that they did not note features of the text such as headings, vocabulary, or graphics. These participants also did not appear to follow the text based on the prompts and cues embedded in vocabulary and headings. Knowledge of text structure facilitates readers' ability to organize data which also affects comprehension and recall (Lorch, Lorch, Ritchey, McGovern, & Coleman, 2001; Meyer, Brandt, & Bluth, 1980). The summaries of participants who did not appear to engage in strategies related to text structure obtained lower scores on the summaries than those participants who demonstrated skill with such strategies.

The attention given to graphics also varied among groups. Instructional level readers generally referenced graphics when prompted in the text. Most instructional level readers looked at the graphics and read accompanying text, suggesting they were responding to the cues provided in the text. However, the majority of participants in the instructional level group did not made attempts to connect the graphic back to the reading or to analyze it further. Specific mention of graphics in the summaries by the instructional level readers suggests that they were able to integrate the information contained within the graphic into their representation of the information (Mayer, 2005). Independent level readers, on the other hand, did engage in analysis to some degree suggesting they were using their knowledge of the text structure to make sense of the new material although graphics were not referenced in the summaries (Mayer, 2005).

Knowledge of content vocabulary is essential to the comprehension of scientific text (Halliday & Martin, 1993). Instructional and independent level readers focused comments on attending to vocabulary, a strategy that was largely overlooked by the frustration level readers. Frustration level readers lack of vocabulary knowledge may have led to frustration and a subsequent loss of interest, which may explain the small number of comments made during the think-aloud in comparison to the other achievement groups (Mikk & Kukemelk, 2010). In the questionnaire, one frustration level reader specifically noted that she felt she was a good reader, unless there were unfamiliar vocabulary terms. The lack of attention to vocabulary by frustration level reads supports the notion that they lack knowledge of shifting strategies (Israel, 2008). The SCLA data supports the findings of the think-aloud protocol, since frustration level readers scored the lowest on the vocabulary question while the independent level readers obtained the highest average score. The independent level readers focused much of their efforts on previewing and reviewing vocabulary during the think-aloud.

Prior Knowledge

The frustration level readers were at a disadvantage due to their low level of prior knowledge about the topics under study and the structure of scientific text, as was evident in the low number of statements made regarding prior knowledge during the think aloud (Kendeou & van den Broek, 2007; Kozminsky & Kozminsky, 2001). SCLA data showed that frustration level readers obtained the lowest average score for the question assessing skill with using prior knowledge which reinforced the results of the think aloud data. Prior domain knowledge has been found to play a large role in the comprehension of text in that it allows readers to make connections with new material encountered in the text (Cromley, Snyder-Hogan, & Luciw-Dubas, 2010; Ozuru, Dempsey, & McNamara, 2009; Samuelsteun & Braten, 2005) . The frustration level readers' lack of prior knowledge explains why fewer statements were made during the think-aloud, especially when reading the viruses text, than in other groups. Without prior knowledge, the frustration level readers were not able to create a mental image of the new information for processing and they did not have a schema into which to integrate the new information, which also became evident in the content and quality of their summaries (Anderson & Pearson, 1984). Frustration level readers performed better when reading the brain article because they were able to make more connections to prior knowledge through personal connections. Instructional level readers placed more focus on unfamiliar content when reading the brain article; the independent and frustration level readers focused more attention on familiar material. As mentioned previously, expert readers tend to focus more attention on new or unfamiliar information as well, indicating the instructional level readers are progressing along a path toward expertise (Lave & Wenger, 1991).

Reading Pattern

Sensitivity to the cues and signals by the achievement groups influenced how they read through the text (Lorch et al., 2001). Frustration level readers engaged in fewer pre-reading strategies than the other groups and the majority read the texts straight through. Differences among groups in reading the brain article showed that instructional level readers focused more on headings than frustration and independent level readers. Instructional level readers also followed prompts and viewed vocabulary terms and graphics more when reading the viruses text than the other two groups. A possible explanation for this trend is the emphasis that had been placed on using such strategies in the school district where the research site was located. The school district had implemented a focus on content area reading strategies several years prior to the study. The school district focused on bringing average achieving students up a level on the state assessment. Many of the instructional level readers may have been involved in these efforts. Strategy instruction has been effective, based on the performance of the instructional level readers; therefore, increased emphasis on teaching frustration level readers to engage in pre-reading activities may increase their awareness and comprehension.

Comprehension Monitoring Strategies

Instructional level participants paraphrased material much more than frustration or independent level readers. Frustration level readers may not have comprehended the article enough to engage in paraphrasing since their prior knowledge of related concepts was lower, in comparison to other groups, as determined by the think aloud data. Summaries of frustration level readers also demonstrated less comprehension compared to the other groups. However, frustration level readers scored on the same level as instructional level readers on the SCLA questions assessing metacognitive and inferencing skills. Although not demonstrated in the think aloud data, this indicated that frustration level readers may possess the ability to use strategies developed through appropriate instructional practices.

Oral Summaries

Based on initial categorization of participants, one would generally expect that the independent level readers would be most proficient in the usage of text structure and comprehension strategies. In the high school classroom, these students are generally assumed to be able to read and comprehend text and are not usually provided instruction in reading strategies. Most of the focus on teaching reading strategies in the classroom is placed on helping the frustration and instructional level readers use vocabulary and to follow the text structure by looking at headings and graphics.

The performance of the participants in the three achievement groups in this study represent the students placed in tech prep, college prep, and honors classes. The frustration level readers represent students who generally would be placed in a tech prep course. These students generally struggle with understanding how to approach scientific text more than other students and are not as successful in transferring reading strategies they have learned in other subjects to science. These students generally do not read outside of the classroom; frustration level readers reported reading fewer than five books outside of school per year. The oral summary content and quality combined score for the brain article was the higher score for the frustration level readers. This demonstrates that participants possess the ability to summarize material that they understand. The brain article offered more opportunities for personal connections than the viruses text, which was a benefit for the frustration level. The instructional level readers represent the average student who may be placed in a college preparatory class. These students have generally learned to utilize the text structure of their textbook well as evidenced by their average score on the summary of the viruses text which surpassed that of the independent group. These students have learned to use the strategies they have been taught when they encounter difficult text. The independent level readers represent students who may be placed in honors courses. These students have generally internalized strategies and are able to read through material in a more automatic fashion when compared to the instructional level readers who demonstrated deliberate use of strategies

The summary data indicate that within each achievement group identified, there is great variation in skill with regard to reading and comprehending scientific text. In broadening the view of each group's level of proficiency in utilizing reading processes with scientific text, an examination of the range of scores for each achievement group provides educators with a different view of how well students in their classes may be able to read and understand scientific text. The discussion above of each group's ability to utilize processes effectively was based on an overall average score, which is a broad generalization. In viewing the individual score range for each summary, it becomes evident that the level of proficiency within each group is very broad. This information shows that science teachers of all levels of students need to teach students how to utilize processes effectively with scientific text.

Triangulation of the Data

Data collected in the think-aloud protocol was triangulated with an SCLA. The average scores for each skill measured on the SCLA were compared to performance during the think-aloud and summary portions of the study.

The SCLA involved reading a short passage and answering questions designed to assess ability with the following processes: (i) prior knowledge, (ii) vocabulary, (iii) metacognition, (iv) inferencing, and (v) summarization. Average scores for each question were compared by group.

The data revealed that when text was available to instructional level readers during completion of the SCLA, they performed more on the level of frustration than independent level readers. This trend was supported by the performance on the metacognition question and the summarization question that required a diagram be drawn. The frustration and instructional level participants' scores were within 0.10 of each other, while the independent level scores were at least 0.70 points higher. Scores for the instructional level were also more in line with the frustration level on vocabulary skill, within 0.30 points, than with the independent level which had an average score 0.70 points higher.

It was expected that average scores on the SCLA questions for the groups would reflect the level of achievement for the groups, with the frustration level at the bottom of the range, the independent level at the top of the range, and the instructional level somewhere in the middle. Several exceptions to that expectation were noted:

1. The frustration level readers garnered the highest average score on the summarization question that allowed participants to select the method by which they summarized the text. Four of the five frustration level participants elected to write a summary and only one elected to draw a diagram. During the think-aloud, participants in the frustration group obtained lower summary scores than the instructional and independent level groups. The frustration level readers demonstrated an ability to summarize text on the SCLA, but fell short of expectations on the oral summaries. This evidence suggests that frustration level participants are better able to summarize text when the text is available. Lengthier texts containing more content may also provide frustration level readers with a greater challenge.
2. The instructional level readers scored slightly above the frustration and independent level readers on inferencing skill. All three achievement groups demonstrated inferencing skill on the SCLA, but few inferences were made by

participants during the think-aloud. The topic of the SCLA was familiar to participants, therefore, it is expected that prior knowledge was higher. Thus, participants were better able to make inferences during the SCLA than with the texts on the brain and viruses, which were unfamiliar topics. Instructional level readers demonstrated the most skill with interpreting text structure during the think aloud which supports their ability to make inferences.

3. The frustration level readers scored slightly above the instructional level on metacognitive skill. Frustration level participants demonstrated some metacognitive skill during the think aloud through statements expressing difficulty with text, recognizing unfamiliar material, and seeking clarification. The frustration level readers demonstrated less metacognitive skill than the instructional and independent groups during the think aloud. This evidence indicates that the frustration level readers' have the ability to monitor and improve their comprehension with instruction in strategies appropriate for scientific text.

When text was not available during the oral summary, instructional level readers performed more like independent level readers. The oral summary scores for the instructional and independent level readers were close to one another for both texts. The instructional level's average content scores were higher than the independent level on both texts. The instructional and independent level reader's average content and quality combined scores were the same for the brain article, but the instructional level scored higher on the viruses text. The texts that participants were asked to read during the think-aloud were also longer than the text used with the SCLA, in order to better reflect what students in a high school science class would be expected to read.

The SCLA processes emerged in the think-aloud data, supporting the findings. In addition to the processes selected for exploration in the SCLA, processes emerged in the think-aloud data that go beyond what was expected. Subtleties such as the various ways graphics were referenced and the manner in which text was read could only be fully realized through a think-aloud.

Discussion

The processes and strategies utilized most frequently by participants resulted in varying degrees of reading comprehension. Although the strategies and processes utilized by participants in this study were grouped as text structure, prior knowledge, reading pattern, and comprehension monitoring strategies, it is acknowledged by the researcher that these processes and strategies are not independent of one another. For example, in order to effectively use a text's structure to guide reading, one must be able to recognize the structure, which is dependent upon prior knowledge of text structure (Lorch & Lorch, 1989). The use of a variety of strategies for the purpose of comprehending text indicates that participants demonstrated cognitive flexibility in because they were able to select strategies to exercise metacognitive thinking in order to fit their needs when reading (Israel, 2008).

Verbalizations during the think-aloud protocol for the frustration level group were fewer in number than for the other groups as expected (Pressley & Afflerbach, 1995). The low level of verbalizations during think-aloud protocol by frustration level readers has been attributed to lower metacognitive skill and low knowledge of strategies (Kozminsky & Kozminsky, 2001; Pressley & Afflerbach, 1995). However, frustration level readers in this study performed well on the SCLA question assessing metacognitive skill which may suggest that these readers possess the skill but lacked the prior knowledge to know how and when to use certain processes.

Independent and instructional level readers in this study possessed prior knowledge of both the topics under study and text structure as evidenced by the think-aloud data and the content of their oral summaries. Instructional level readers were adept at utilizing the text structure as they reacted to the cues provided by the headings and vocabulary. Frustration level readers' use of strategies was not as varied and well-developed as the instructional and independent level readers, indicating the frustration level readers had a lower level of prior knowledge about the topics under study (Kendeou & van den Broek, 2007; Kozminsky & Kozminsky, 2001).

Independent level readers' average summary score was affected by one participant's score of zero as he stated he did not understand anything he read because it did not interest him. The role of interest in the topics of the instruments used in this study was not specifically investigated but the data collected from the questionnaire regarding favorite subjects indicates that science was not a subject of great interest to most participants, which may have played a role in how participants interacted with the texts (Mikk & Kukemelk, 2010). In fact, four participants specifically mentioned level of interest in their assessment whether or not they were a good reader. Independent readers, having greater prior knowledge as measured by the cloze assessment, were expected to have better comprehension than the instructional level readers. However, the oral summaries indicated that many instructional level readers were better able to recall and organize information in their summaries, which supports Greene's (2001) findings that more than one measure of comprehension is needed to assess a reader's ability to comprehend the macrostructure of a text.

The concern for science teachers is data showing that over half of instructional and independent level readers are capable of utilizing higher order processes such as synthesizing and clarifying, but such processes were not largely utilized by most participants in a group with either text. This provides needed information on where to begin when scaffolding students toward disciplinary practices. The think-aloud data collected in this study has provided information that demonstrates that even high achieving readers experience great difficulty with scientific text and need specific instruction in how to effectively read and comprehend text.

Limitations

Limitations on the interpretation of results of the study must be considered. First, achievement groups were determined based on cloze test scores. The cloze has been found to be a reliable predictor of reading comprehension, which encompasses prior knowledge (Bormuth, 1968). However, prior knowledge was not assessed independently due to the interactive nature of such knowledge with comprehension processes. The score range associated with each achievement group was based on research aligning cloze scores with other assessments of reading. The score range does have some variability

(Rankin & Culhane, 1969). For example, a frustration level participant scoring a 39 on the cloze may have placed in the instructional group using another assessement.

Second, the texts used in the study were limited to biology texts and were focused on one broad knowledge domain, thus limiting the generalization of results beyond texts addressing this domain.

Third, the generalization of results is limited to population similar to the population from which the sample for the study was drawn. For example, results could be generalized to other high school students reading scientific text with similar interests and academic experiences, but could not be generalized to middle school or college populations.

Fourth, the texts used in the study represented popular science magazines and textbooks. Interpretation of the results of this study is limited to these two types of text. For example, results cannot be generalized to the reading of scientific research reports.

Finally, analysis of the think-aloud protocols, while verified by a second rater, were likely influenced by the researchers own experiences. Therefore, interpretation of the results should acknowledge that possibility.

Recommendations for Instruction

The current study adds to the literature in that it has demonstrated (i) the processes students categorized as frustration, instructional, and independent readers utilized while reading scientific text without prompting; (ii) processes utilized while reading texts that are found in the science classroom, and (iii) that students are capable of utilizing a variety of processes as demonstrated by one time use. Recommendations for curriculum design aimed at improving high school students' disciplinary literacy practices in science are as follows:

1. *Increase the focus on interpreting graphics in the science classroom.*

Since general strategies such as previewing headings and vocabulary were used frequently while careful study and interpretation of graphics was not, this indicates that this skill has not been demonstrated for students in the context of the science classroom.

The Common Core Science Standards (National Governors Association Center, 2010a) call for students to be able to translate information expressed visually into words by the end of their senior year of high school. Based on the results of this study, the group of mostly sophomore and juniors are not on target to meet that goal, as the majority of students simply glanced at the graphics. Frustration level readers spent very little time, if any, focusing on the graphics. This issue is likely rooted in the practices of teachers in terms of their treatment of graphics. Coleman, McTigue, and Smoklin (2011) noted that over 90 percent of elementary teachers in their study did not take time to model the interpretation of graphics when reading with their students. They also noted that the most frequent type of graphic encountered in their experiences were flow diagrams. The flow diagram of the lytic and lysogenic cycles posed a great deal of difficulty for many participants in this study as they did not know how to read it. One frustration level reader, in particular, experienced difficult as she struggled to describe what she saw which was likely due to the lack of detailed explanations (Pinto & Amettler, 2002). Students cannot learn the habits of the science discipline if they are not exposed to them in context, which may explain the treatment of graphics by students in this study.

Teachers can facilitate making graphics more accessible to students by demonstrating how to interpret visuals so that when students encounter a complex graphic they are not experiencing cognitive overload and learning can be enhanced (Cook, 2008; Kirschner, 2002; McTigue & Flowers, 2011; Pinto & Amettler, 2002; Paas, Renkl, & Sweller, 2004). Mayer's (2005) cognitive theory of multimedia learning stresses the importance of learners understanding how to select relevant information from graphics in order to avoid cognitive overload from images such as the lytic and lysogenic cycle graphic from the viruses selection.

2. Provide students with more varied forms of scientific text.

All levels of readers exhibited comfort with the structure of the textbook because it is perhaps the only form of scientific text most students have read. Most participants were hesitant in their previewing attempt, as well as in their search for important vocabulary in the *Discover* article since bold headings and terms were not included throughout the article.

Participants attempted to apply the same pre-reading strategies to the magazine article as they did the textbook article but they encountered difficulty as the magazine article did not include large section headings or bolded vocabulary. Falk and Yarden (2009) encountered a similar phenomenon with students in their study as they interacted with adapted primary literature. Students in their study were not sure how to approach the text, leading them to skip important sections. Varying text type will allow students to build a wider base of strategies for use when encountering a variety of texts.

If students are to begin developing the disciplinary skills of experts, they must have exposure to varied texts and be given the opportunity to work with those texts in an authentic manner. Teachers can facilitate the process by including varied texts in the curriculum but they must scaffold methods that allow students to learn how to appropriately interact with those texts (Lave & Wenger, 1991).

3. Teach strategies to frustration level students.

Frustration level readers, in particular, demonstrated a lack of skill in utilizing cognitive strategies. As strategy instruction with lower-achieving students has been found to improve comprehension (Kozminsky & Kozminsky, 2001; Verville, 1985) specific instruction in strategy use is recommended for these students. In keeping with disciplinary literacy goals, instruction of such strategies should be within the context of science and should place emphasis on the content first (McKeown et al., 2009). Modeling the use of multiple strategies interactively is also recommended as this would allow frustration level reader's to make connections among strategies.

4. Encourage summarization activities in the science classroom.

Participants' summaries in this study were not organized and in some cases were extremely brief. Strengthening connections to prior knowledge and facility with text structure contribute to students' ability to organize the information learned from text. (Meyer, Brandt, & Bluth, 1980; Ozuru, Dempsey, & McNamara, 2009). Students need specific work with higher order processes and strategies such as summarization in science due to the challenges presented by scientific text. Summary skills should be developed using a variety of scientific texts in order for students learn how to navigate various pieces of text.

5. Multiple forms of assessment should be used to identify disciplinary literacy processes.

The cloze test provided information of participants' familiarity with scientific text and the SCLA provided additional insight on strengths and weaknesses with regard to specific disciplinary literacy processes. These two forms of assessment should be supplemented with a think-aloud protocol and measure of comprehension in order to discern the predicted versus actual processes utilized by students when reading. The think-aloud also allows teachers to gain insight into what processes students are using while reading when not prompted by questions.

Implications for Future Research

Findings from this study lead to additional avenues of research in the future. As this study involved a relatively small sample size, a study examining a large number of students in more than one location would further develop the understanding of processes students' use when reading scientific text.

While this study was able to provide information about the processes lower achieving students use when reading scientific text, further study is needed on this population since the sample size was very small in this study. Perhaps a larger sample size could be obtained by utilizing additional measures to identify achievement level. Future studies may consider reviewing class grades, standardized test scores, and formative assessment scores in reading and science in order to group students.

Additionally, an opportunity to observe and assess frustration level readers in the natural classroom setting would be beneficial as these students are less likely to volunteer to participate in a reading study.

Instruction in how to read and interpret graphics in scientific text has been recommended. Future studies of the effects of instruction on interpreting graphics would further develop an understanding of how to best proceed with disciplinary literacy instruction in the high school science classroom.

Closing

The study examined the processes utilized by high school students reading scientific text. Results showed that processes were concentrated around strategies addressing text structure, prior knowledge, reading pattern, and comprehension monitoring. Differences were found to exist between the processes utilized by each group. Comprehension of scientific text varied within and between achievement groups. Results indicate that high school students' ability to comprehend text is affected by their familiarity with the text structure in addition to prior domain knowledge as these factors the ability to activate schema. In light of the Common Core Standards for literacy (National Governors Association, 2010b), classroom instruction that focuses on providing students with experiences with multiple types of text and practice in utilizing processes and strategies appropriate for the discipline are needed to prepare students to meet the new standards.

APPENDICES

Appendix A

Participant Questionnaire

1. Name:
2. Circle your current grade level: 9, 10, 11, 12
3. Circle your gender: Male Female
4. Circle your current age: 14, 15, 16, 17, 18
5. Please fill in your class schedule so that I may reach you if needed:

Traditional Schedule Course Name	Skinny Schedule Course Name	Teacher	Traditional Schedule	Skinny Schedule	Teacher
1A	1A		1B	1B	
	2A			2B	
2A	3 A		2B	3B	
	4A			4B	
3A	5A		3B	5B	
	6A			6B	
4A	7A		4B	7B	
	8A			8B	

6. Do you like to read? If so, what do you like to read for enjoyment? (Ex. Science fiction, graphic novels, romance novels)
7. Approximately how many books do you read in a year that are not part of a school assignment? In other words, how many books do you read for fun?
8. Do you feel like you are a good reader when it comes to your classes at school? Why or why not?
9. Is there any one subject that you dislike more than the others? Why?
10. Is there any one subject that you like more than the others? Why?

Appendix B

Cloze Assessment

Cell Cycle

There are three main stages of the cell cycle. _1___is the stage during __2___the cell grows, carries_3___cellular functions, and replicates, __4___ makes copies of its __5___in preparation for the __6___stage of the cycle._7____ is divided into three __8___. Mitosis is the stage __9__the cell cycle during ___19_the cell's nucleus and __11___material divide. Mitosis is __12_ into four substages. Cytokinesis __13___the method by which __14_ cell's cytoplasm divides, creating __15__new cell.

Interphase is __16__into three stages: G1, __17__and G2. The first __18__of interphase, G1, is __19__ period immediately after a __20__ divides. During G1, is _21___ period immediately after a __22_ divides. During G1, a _23___ is growing, carrying out __24__cell functions, and preparing _25___ replicate DNA.

The second __26__ of interphase, S, is __27__ period when a cell __28__ its DNA in preparation __29__ cell division. Chromosomes are __30__structures that contain the __31_ material that is passed __32__ generation to generation of __33___.

The G2 stage follows the S stage and is the period when the cell prepares for the division of its nucleus.

Reference

Biggs, A., Hagins, W.C., Holliday, W.G., Kapicka, C.L., Lundgren, L., MacKenzie,A.H., Rogers, R.D., Sewer, M.B., & Zike, D., (Eds.) (2008). *Biology*. (p. 246-247) New York: McGraw-Hill

Appendix C

Cloze Assessment - Answer Key

Cell Cycle

There are three main stages of the cell cycle. Interphase is the stage during which the cell grows, carries out cellular functions, and replicates, or makes copies of its DNA in preparation for the next stage of the cycle. Interphase is divided into three substages. Mitosis is the stage of the cell cycle during which the cell's nucleus and nuclear material divide. Mitosis is divided into four substages. Cytokinesis is the method by which a cell's cytoplasm divides, creating a new cell.

Interphase is divided into three stages: G1, S, and G2. The first stage of interphase, G1, is the period immediately after a cell divides. During G1, a cell is growing, carrying out normal cell functions, and preparing to replicate DNA.

The second stage of interphase, S, is the period when a cell copies its DNA in preparation for cell division. Chromosomes are the structures that contain the genetic material that is passed from generation to generation of cells.

The G2 stage follows the S stage and is the period when the cell prepares for the division of its nucleus.

Reference

Biggs, A., Hagins, W.C., Holliday, W.G., Kapicka, C.L., Lundgren, L., MacKenzie, A.H., Rogers, R.D., Sewer, M.B., & Zike, D., (Eds.) (2008). *Biology*. (p. 246-247). New York: McGraw-Hill

Appendix D

Think-aloud Protocol Procedures

Today, you will be participating in a think-aloud study. You will be audiotaped and videotaped during your session in order to help me remember all that you say. These tapes will be used for this purpose only.

Reading Instructions: You will be asked to read two passages, one from a textbook and one from a science magazine. You are asked to say what you are thinking as you read. After reading each passage, you will be asked to provide an oral summary. You will not be able to look at the text as you summarize.

Appendix E

Oral Summaries Scoring Rubric

<u>Content Score</u>

Summaries were scored based on the following criteria in order to assess comprehension:

- (+5) five points were awarded for an overall main idea
- =(+1) one additional point was awarded for each correct supporting detail
- (-1) one point was subtracted for each incorrect detail

<u>Quality Score</u>

Summaries were scored based on the following criteria in order to assess the quality of the summary:

- (+0) zero points for isolated details with no explanation;
- (+5) five points for details with explanations;
- (+10) ten points for details with explanations that were connected to form a coherent summary

Appendix F

Strategic Content Literacy Assessment (SCLA) – Reading Passage

Prokaryotic Structure

Prokaryotes are microscopic, unicellular organisms. They have some characteristics of all cells, such as DNA, and ribosomes, but they lack a nuclear membrane and other membrane-bound organelles, such as mitochondria and chloroplasts. Although a prokaryotic cell is very small and doesn't have membrane-bound organelles, it has all it needs to carry out life functions.

The chromosomes in prokaryotes are arranged differently than the chromosomes found in eukaryotic cells. Their genes are found on a large, circular chromosome in an area of the cell called the nucleoid. Many prokaryotes also have at least one smaller piece of DNA, called a plasmid, which also has a circular arrangement.

Some prokaryotes secrete a layer of polysaccharides around the cell wall, forming a capsule. The capsule has several important functions, including preventing the cell from drying out and helping the cell attach to the surfaces in its environment. The capsule also helps prevent the bacteria from being engulfed by white blood cells and shelters the cell from the effects of antibiotics.

Structures called pili are found on the outer surface of some bacteria. Pili are submicroscopic, hairlike structures that are made of protein. Pili help bacterial cells attach to surfaces. Pili also can serve as a bridge between cells. Copies of plasmids can be sent across the bridge, thus providing some prokaryotes with new genetic characteristics. This is one way of transferring the resistance to antibiotics.

<u>Reference</u>

Biggs, A., Hagins, W.C., Holliday, W.G., Kapicka, C.L., Lundgren, L., MacKenzie, A.H., Rogers, R.D., Sewer, M.B., & Zike, D., (Eds.) (2008). *Biology*. (p. 518).New York: McGraw-Hill

Appendix G

SCLA Questions

Please answer the questions based on what you just read.

1. What did you know before you read the text that relates to the information it contains about prokaryotic structure?

2. Use a diagram, concept map, or summary to summarize the most important ideas from the text.

3. The text discusses features of prokaryotic cells. Based on what you have read, how do you think prokaryotic cells differ from eukaryotic cells?

4. Define the following terms from the text *and* explain how you gathered the meaning of the words:

a. plasmid

b. chromosome

c. bacteria

5. Did you find this task easy or hard? What made it easy or hard and how were you able to help yourself understand the information in the text?

6. Based on the text, draw and label a diagram of a prokaryotic cell.

Appendix H

SCLA Questions – Answer Key

Please answer the questions based on what you just read.

1. What did you know before you read the text that relates to the information it contains about prokaryotic structure?

Prokaryotes are single-celled. Bacteria are prokaryotes.

2. Use a diagram, concept map, or summary to summarize the most important ideas from the text.

Prokaryotes are single-celled an contain circular DNA. A polysaccharide capsule protects bacteria from antibiotics.

3. The text discusses features of prokaryotic cells. Based on what you have read, how do you think prokaryotic cells differ from eukaryotic cells?

Prokaryotes are single celled and eukaryotes are multi-celled. Prokaryotes do not contain a true nucleus or membrane-bound organelles like eukaryotes.

4. Define the following terms from the text *and* explain how you gathered the meaning of the words:

a. plasmid – *piece of DNA are not part of the chromosome.*
b. chromosome – *genetic material, DNA. It is circular in prokaryotes*.
c. bacteria - *prokaryotic cells*

5. Did you find this task easy or hard? What made it easy or hard and how were you able to help yourself understand the information in the text?

Answers will vary. Full credit for supporting statement

6. Based on the text, draw and label a diagram of a prokaryotic cell.

Diagrams should include: cell wall, capsule, nucleoid, circular DNA, plasmid, ribosome

Appendix I

SCLA Scoring Rubric

	0	**1**	**2**	**3**	**4**	**5**
Connection	No response.	Student did not make a connection to prior knowledge.		Student made a connection to prior knowledge but did not provide evidence for prior knowledge.		Student made a connection to prior knowledge and provided evidence for their prior knowledge.
Summarize	No response.	Student did not summarize the main ideas accurately.		Student summarized some of the main ideas accurately.		Student summarized the main ideas accurately.
Inference	No response.	Student did not make an inference **or** student made an unrealistic inference but did not support it.		Student made a realistic inference based on the text but did not support it **or** Student made an unrealistic inference and supported it.		Student made a realistic inference based on the text and supported it.
Vocabulary	No response.	Student did not accurately define vocabulary.		Student accurately defined some vocabulary.		Student accurately defined all vocabulary.
Metacognition	No response.	Student was not able to explain their method of cognition/ understanding.		Student was somewhat able to explain their method of cognition/ understanding.		Student was able to explain their method of cognition/ understanding.

Alvermann, D.E., Gillis, V.G., & Phelps, S.F. (2013). *Content area reading and literacy: Succeeding in today's diverse classroom* (7th ed., Kindle version). New York: Pearson.

Appendix J

Descriptions of Codes

Code	Description	Example statement
Acknowledges familiar terms or content	Participant verbalizes in general terms that they have familiarity or prior knowledge of terms or content.	Ex. "I remember doing replication of DNA and RNA and how the letters hook up with letters on the other side."
Clarification	Participant rereads or reasons to work through material they do not understand.	Ex. "Skimming back through viruses and prions to see if I can connect the dots."
Contradictory statement	Participant contradicts a statement they previously made.	Ex. "Okay the lytic cycle – the chart isn't very detailed. It doesn't show exactly where it starts." The graphic the participant was referencing was extremely detailed. The participant previously stated that the chart "was very detailed."
Describing	Participant tells what the text or graphic was about in very broad terms with no detail. For example, "it was about the brain."	Ex. "It talks about how it makes copies of viral RNA or DNA and how it instructs the viral cell to make more enzymes and proteins for the viral replication."
Expresses difficulty interpreting graphic	Participant verbalizes that they are having trouble interpreting a graphic.	Ex. "I guess I'm going to go back and read the lytic cycle and the lysogenic cycle because I barely know what's going on." (Here, the participant was referencing a graphic of the lytic and lysogenic cycles.)

Appendix J

Descriptions of Codes

Code	Description	Example statement
Expresses difficulty interpreting text	Participant verbalizes that they are having trouble understanding what they are reading.	Ex. “And now I’m flipping back and forth pages ‘cause with all honesty, I don’t know what I just read.”
Graphic reference-reads captions	Participant states that they read the caption of one or more graphic.	Ex. “Okay, so I’m looking at the pictures and the captions to explain what I’m reading.”
Graphic reference -skimming	Participant acknowledges skimming over graphic and/or caption.	Ex. “I look at the timeline and skim through it.”
Graphic reference- only notes "picture" with no description or mention of caption, etc.	Participant does not indicate specifically which graphic they are viewing. Instead they use general terminology such as “the picture”.	Ex. “I go the read but the chart catches my eye and I look at it. I just glance at things on the chart.”
Graphic reference- specifies graphic by number, title, or content	Participant identifies graphic they are viewing by title, number, or content.	Ex. “I read through the lytic cycle on Figure 18.13.”
Graphic reference- specifies that graphic is viewed after prompting in the text	Participant states that they are looking at graphic because it was mentioned in the text.	Ex. “I see Figure 18.13 mentioned, so I look for it.”
Graphic reference-moves between graphic and text	Participant acknowledges returning to a previously viewed graphic after further reading.	Ex. “Once I read about the figures, I go back again and look at it so I can actually understand it.”

Appendix J

Descriptions of Codes

Code	**Description**	**Example statement**
Intratextual connection	Makes connections between claims within the same text.	Ex. “I didn’t understand the first description of the ultrasound method until I read the second paragraph but now that explains it.”
Memorizing	Attempts to memorize information.	Ex. “I pause trying to pronounce this man’s name, his first name is Paul. Apparently he cured syphilis. I will try to remember that.”
Navigates	Participant tells what section or graphic they are looking at with no additional information.	Ex. “First I look at the bold words at the top to kind of get an idea of what’s going on and then I basically start reading all the rest of it.”
Numerical reference	Participant references numerical values.	Ex. “It says that a virus can be from 5 to 300 nanometers which is really, really small.”
Order of reading - break in pattern	Participant reads text in a different order than presented.	Ex. “I’m kind bored so I’m going to go ahead and read the side text on the left.”
Order of reading graphics first	Participant looks at graphics first.	Ex. “I first look at Figure 18.2 at the bottom it has bright colors, so it draws my attention
Order of reading margins first	Participant looks at text in the margins first.	Ex. “I usually look at the vocab first.” (The vocabulary terms were noted in the margin of the text).
Order of reading straight through	Participant reads text in order presented.	Ex. “I look at the statement at the top first and I read the main paragraph.”

Appendix J

Descriptions of Codes

Code	**Description**	**Example statement**
Paraphrasing	Summarizing text in participant's own words.	Ex. “Okay so then like back to the membrane thing it says that certain cells can’t get through the membrane because of the blood brain barrier but others can that are around the same size.”
Personal connections	Makes a personal connection with the text.	Ex. “I see Alzheimer’s disease, Parkinson’s disease, and I know about both of those because they’re kind of prevalent in my family, so I’ve heard about both of them kind of first hand.”
Predicting	Participant uses the text to predict how something will work or simply what type of information is likely to follow.	Ex. “It’s talking about animal trials which I guess lead me to believe that they haven’t done any human trials yet and they don’t know that it will work on humans.”
Preview headings	Use title and/or headings to get an idea of what the text is about.	Ex. “When I first look at this article I’m reading the title and any headings.”
Previews author	Reads side note about author or inquires about the author.	Ex. “I look and see who wrote it then I begin reading.”
Questioning	Participant poses a question in response to the text.	Ex. "How does the blood brain barrier act as a filter?"
Recognition of unfamiliar material	Participant states they do not know or did not know something presented in the text.	Ex. “I didn’t realize the brain had so many parts.”
Remark random	Participant makes a remark that has nothing to do with the text.	Ex. “I don’t know that would be kind of cool if you had tie- dyed tissues- that would be a pretty weird x-ray scan.”

Appendix J

Descriptions of Codes

Code	Description	Example statement
Remark text based	Participant makes a remark that is based on something read in the text.	Ex. “That’s interesting that the blood brain barrier keeps infection from other parts of the body away from the brain.” Text based remarks differ from description in that they are not specifically attempting to describe a process to demonstrate understanding.
Rereading	Rereading for clarification.	Ex. “I’m going to read that paragraph again that starts ‘it wasn’t until 1980.’ That just doesn’t make sense to me yet, so rewinding.”
Skimming for preview	Skims headings, text, or graphics prior to reading to ascertain general content of the piece of text.	Ex. “I skim over it, look at everything to get a general understanding of what’s going on and then start reading the text.”
Skimming for review	Participant skims back through all or a portion of the text when finished reading.	Ex “I just finished this page and I’m looking back over it to make sure I’ve covered everything.”
Synthesis	Synthesis of new claims with pre-existing ideas in order to come to a new understanding.	Ex. “That may be another reason viruses aren’t considered living because it says they have to have a host cell so anything that’s living can live on its own.”
Skipping text or graphic	Skips over text or graphic purposefully.	Ex. “There was a picture on the second picture with a heading but I didn’t read it or look at it”

Appendix J

Descriptions of Codes

Code	Description	Example statement
Text structure-color or highlight	References text by color or as highlighted.	Ex. “Then I skip to the bold terms that are highlighted and read the sentence before it and the sentence after it.”
Text structure-font	References size of text.	Ex. “When I first look at the article, I’m going to look at the top where it says “maybe you do need a hole in your head.” It’s the biggest text, so it’s what catches my attention first.”
Unsupported or incorrect claim	Claim is not accurate or is not supported in text.	Ex. “I knew that Alzheimer’s and Parkinson’s disease were types of brain cancer.”
Verbatim reading	Participant reads text aloud verbatim.	Ex. “Biologists found they could see the microscopic structure of the body if they injected tissues with special dyes.”
Visualizing	Participant acknowledges that they are visualizing information they currently reading about in the text.	Ex. “I’m picturing the brain as it’s describing it, the molecules that the brain requires. I’m thinking about the invisible barrier it’s trying to describe. Now I’m thinking about the different types ways they describe to get across the barriers.”
Vocabulary	Participant specifically refers to content vocabulary.	Ex. “Here’s another vocabulary word called the lytic cycle.

Appendix K

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