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READ, RETRIEVE, CONNECT AND USE: AN INTERVENTION STRATEGY FOR
SCIENCE AND SCIENTIFIC LITERACY

By

Kerryane T. Monahan

A Dissertation in Practice

Submitted in partial fulfillment of the requirements for the degree of

Doctorate in Education

Doctoral Program in Educational Leadership at Lynn University,
College of Education

Lynn University

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READ, RETRIEVE, CONNECT AND USE: AN INTERVENTION STRATEGY FOR
SCIENCE AND SCIENTIFIC LITERACY

Kerryane T. Monahan. Ed.D.

Lynn University, 2012

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READ, RETRIEVE, CONNECT AND USE: AN INTERVENTION STRATEGY FOR SCIENCE AND SCIENTIFIC LITERACY

Abstract

American students underachieve on local, state, national, and international assessments of science. Student performance on standardized assessments has driven numerous educational reforms including No Child Left Behind and Race to the Top with a resulting increased focus on student achievement. Local districts and schools struggle with how to improve student achievement in order to meet the requirements of state and federal legislation. International and national government officials extoll the value of science in driving the economic prosperity of a nation adding increased pressure to improve science scores in the United States. Moreover, to be effective decision-makers personally and within a democracy, citizens must be scientifically literate. Read, Retrieve, Connect and Use (RRCU) is an instructional strategy that combined state biology content standards, with the new Common Core Standards for Literacy in Science through evidenced-based literacy strategies recommended by the National Reading Panel. This study aimed to assess the efficacy of an intervention, RRCU to improve science content knowledge and literacy skills in Biology and Language Arts. The findings identified reading skill, as measured by FCAT Reading as predictive of Biology test scores indicating a close relationship between reading comprehension and the ability to learn and be assessed on science content knowledge. The data did not indicate RRCU was an effective means of improving student science content knowledge or literacy skills. However, teachers responded positively to the strategy as a means to reinforce content knowledge and support literacy skills. Future recommendations include improving the study design and expanding the use of the strategy to middle school to build a foundation of effective literacy skills students can use to cope with the depth and complexity of science content at the high school level.

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CHAPTER 1: INTRODUCTION

American students underachieve on local, state, national and international assessments of science. Student performance on science assessments has, in part, driven educational reforms including No Child Left Behind (NCLB) (U.S. Department of Education, 2004) and the current Race to the Top (RttT) legislation at the federal level (The White House, 2009). International data indicated American students lag behind many of their counterparts in reading, math and science, spurring debate on the state of public education in the United States (Fleischman et al., 2010; Gonzales et al., 2008). At a local level, districts struggle to raise student achievement to meet the requirements of NCLB and RttT (Kober, Chudowsky, and Chudowsky, 2010). Many districts implemented benchmark tests as a mechanism to assess student progress and drive instruction to improve student achievement on state standardized tests.

With the advent of more accountability in public education and the resultant increase in the number of standardized tests across subject areas there has been a renewed focus on the quality of the tests and exactly what those tests are measuring. A large study by O'Reilly and McNamara (2007) indicated that reading skill is a significant predictor of science achievement both in terms of course grades and state exam scores. This study revealed that students with lower level scientific knowledge but higher level reading skills outperformed students with higher level scientific knowledge and lower level reading skills.

A recent study by Visone (2009) questions the validity of standardized testing in science. The study examined student scores on state tests of science and reading, a

positive moderate-to-strong relationship existed between students' achievement on the science content knowledge and nonfiction reading assessments. Visone concluded that science tests assess reading, not exclusively content knowledge, which aligns with the assertion by RAND (2002) that poor performance by American students relative to their international counterparts is connected to their poor reading skills.

Supporting this conclusion are the results of a study that examined the impact of a reading accommodation for learning disabled students on a standardized test. The accommodation for these students was to have the science test read aloud. The authors included a comparison group of non-disabled students who also were provided the accommodation and a control group that received no intervention. To the surprise of the investigators, the read aloud accommodation not only positively impacted the learning disabled students' scores but also those of the non-learning disabled students (Meloy, Deville, & Frisbie, 2000). Clearly, it is imperative that educators support the development of student reading skill in addition to scientific knowledge if the goal is to improve student achievement on standardized tests in science.

Why should we care about student achievement in science? The Organization for Economic Co-Operation and Development (OECD) claimed that, "science, technology, and innovation are now key to improving economic performance and social well-being (OECD Observer, 2000)." Innovation and technology play a vital role in the economic prosperity of the United States and other OECD countries driving a need for educational organizations to provide skilled personnel. Nancy Pelosi (U.S. House Speaker) speaking at the "Innovation Agenda" roundtable at Princeton University in 2008 iterated, "science,

science, science, science. We stand by this as the most important investment that we can make in health and education and energy independence, job creation and the defense of America.” U.S. Representative Rush Holt asserted that, “Science and scientific research are not luxuries to be engaged in in plush times, but rather they are the basis for economic growth, economic prosperity and quality of life.” Given the current economic situation of the United States, the mediocre performance of U.S. students on science assessments becomes more concerning.

If science, technology and innovation are connected to economic prosperity and quality of life we need to ensure that all students are being adequately educated in these fields. Yet science assessments reveal an achievement gap between socioeconomic and racial groups. No Child Left Behind led to greater accountability for schools, but that accountability has so far only made evident the achievement gap but has failed to close the gap. The National Assessment for Educational Progress (NAEP) science assessment begun in 1990 indicated that boys outperform girls, whites and Asians outperformed African Americans and Latinos, and students from higher socioeconomic groups do better than students from lower socioeconomic groups (National Center for Education Statistics, 2005; National Center for Education Statistics 2009).

Li, Klahr, and Siler (2006) identified two components to the achievement gap: the learning gap and the test gap. In their study, they focused on improving instruction by using research-based strategies and emphasizing mastery of content standards over breadth of content standards. Consequently, teachers covered only one third of the topics normally covered but assessment items from the NAEP and TIMSS on those topics

revealed students were scoring above the U.S. average and on par with international leaders (a narrowing of the learning gap). However, student scores on state tests did not significantly change (no closing of the test gap). The authors suggested this represents the impact of prior knowledge which could account for up to 40% of the test gap. Of interest to the current study, prior knowledge is also connected to reading skill level.

Statement of Problem

Students are underachieving on standardized science tests as evidenced by results on international assessments including the Trends in International Mathematics and Science Study (TIMSS), Program for International Student Assessment (PISA), and Progress in International Reading Literacy Study (PIRLS). NCLB and RttT have emphasized student standardized test scores in evaluating the efficacy of public schools, leading schools to focus on standardized test preparation. To this end, many schools and districts implemented benchmark testing to assess student progress in preparation for state and national standardized tests. However, research suggests that tests of content-knowledge, such as a standardized or benchmark science test, may in fact be assessing reading ability (specifically of informational text) more than content knowledge (Visone, 2009). Therefore, to improve student achievement on science tests, schools must improve student reading skill and comprehension of informational text while maintaining or building on science content knowledge.

An added layer of complexity is brought about through the adoption of the Common Core Standards which outline standards for scientific literacy. Teachers must combine their current state standards for science with the Common Core Standards for

scientific literacy and prepare students for standardized testing both at the local level (benchmark testing) and the state/national level as the assessments of the Common Core Standards are implemented. Currently, there are no curricular materials that combine the Florida Next Generation Sunshine State Science Standards, the Common Core Standards for Scientific Literacy and instructional strategies to improve reading comprehension of informational text for either high school or middle school science courses. Three research issues related to this study are student achievement in science, scientific literacy and the Common Core Standards and the impact of NCLB and RttT on schools, teachers and students specific to science education.

Student Achievement in Science

The performance of U.S. students in science has been stagnant and/or in decline on multiple measures including the National Assessment of Educational Progress (NAEP), the Program for International Student Assessment (PISA), and the Florida Comprehensive Assessment Test (FCAT). The newly revised NAEP, administered in 2009, measured students' knowledge of physical science, life science, and the Earth and Space sciences. Just 34% of 4th graders 30% of 8th graders and 21% of 12th graders scored at or above proficient with less than 2% scoring at the advanced level in any grade. Also of concern, there is a significant gap in science achievement with White and Asian/Pacific Islander students significantly outperforming Black and Latino students. Students in suburban schools outperformed students in city and town schools, and on average boys performed slightly better than girls across categories. Particularly relevant to this study, Florida students in 4th grade scored on average with the rest of the nation

and 8th grade science scores were below the national average. (National Center for Educational Statistics, 2009)

The most recent administration of the PISA in 2009 was designed to assess the scientific literacy of students which measures content knowledge but also the ability to explain phenomena, to draw evidenced-based conclusions and the awareness of how science and technology impact and shape our society (Lau, 2009). The average score in 2009 was 500 and U.S. students scored an average of 502 ranking the U.S. 17th among other Organization for Economic Cooperation and Development (OECD) countries but also behind non-OECD countries such as Singapore, Liechtenstein, Hong Kong, and Macao. On a positive note, U.S. students improved their performance in 2009 from 2006 when the average score was below the OECD average. (Highlights from Pisa, 2009)

Another international assessment, the Trends in Mathematics and Science Study was administered in 2007 and designed to assess both content knowledge and cognitive skill level (knowing, applying, reasoning). In this assessment, U.S. students in 4th and 8th grade scored above the average for participating countries with scores of 539 and 520 compared to an average score of 500 (Highlights from TIMSS, 2007). It is impossible to directly compare TIMSS results with PISA results as the participating countries in each assessment vary. Countries that outperformed the United States on the TIMSS included Singapore, Japan, England, Hungary, and the Russian Federation.

The Florida Comprehensive Assessment Test (FCAT) in Science was administered in 8th grade and 11th grade. The trend in performance at both grade levels since initial implementation is a rise in scores. Student scores in 8th grade have

incrementally risen each year starting at 28% scoring proficient or better in 2003 to 46% in 2011. Scores of 11th grade students have improved from 33% proficiency or better to 40% in 2011. (Florida Department of Education, 2011) Since the tests have undergone numerous revisions, including the elimination of open response questions, it is not possible to assess if rising scores correlate to an increase in student knowledge.

Currently, FCAT is undergoing another significant revision and will shift towards end-of-course exams including high school Biology in 2012.

While achievement remains low across the board on science FCAT, a more ominous trend becomes evident when scores are disaggregated. While 52% of White students scored proficient or better in 2011, just 34% and 20% of Latinos and African-Americans did so respectively in 11th grade. (Florida Department of Education, 2011). All groups did better in 8th grade with 59% of Whites, 40% of Latinos, and 24% of African-Americans scoring proficient or better in 2011. There is wide variation among districts in terms of science achievement. The district in this study falls below state averages for proficiency with 8th graders at 43% proficiency or better and 11th graders at 33% proficiency or better. Disaggregation of data at the district level reveals 25% of African-Americans scoring a 3 (proficient) or better compared to 54% of White children in 8th grade. More concerning is that 39% of African-Americans are scoring a 1 (lowest achievement level) compared to just 14% of Whites and 21% of Latinos. Scores at the 11th grade level are similar with 46% of white students scoring a 3 or more compared to 17% of African-American and 25% of Latino students. (Florida Department of Education, 2011)

Scientific Literacy and the Common Core Standards

The term “scientific literacy” has been bantered about by politicians and educators alike. Recent reforms have made a concerted push towards developing “scientific literacy” among students yet the term has yet to be clearly defined and often times is used in contradictory manners. Politicians frequently make arguments that the economic prosperity of the country requires a cadre of elite and well-trained scientists and engineers (President Obama’s address to the National Academies of Science, 2009) while at the same time 48 states have signed on to the Common Core Standards which focus on developing the ability to read scientific text for understanding without emphasis on actual or specific scientific content (Common Core Standards, 2011).

It might be more useful to identify dimensions of scientific literacy such as practical, civic, and cultural (Dillon, 2009) whereby practical literacy address content knowledge, civic literacy refers to the knowledge and skills required for informed public debate, and cultural literacy addresses the need to know about science as a significant human endeavor. Such specificity in definition would permit better development and organization of science curricula that would address the multiple needs of the nation in developing both a cadre of scientists and in developing good and effective citizens that can appropriately participate in our democracy.

Read, Retrieve, Connect and Use

The intervention under study is the Read, Retrieve, Connect & Use (RRCU) strategy developed and implemented by the author as a life science teacher in a highly-diverse, urban secondary school setting. The RRCU strategy was designed to provide opportunities for students to make connections from course content to current scientific practice using informational text passages from well-known science publications. Sources included National Geographic, Discover, Smithsonian, various science journals and sciencedaily.com. It became evident that many students struggled with reading these passages and lacked specific strategies to achieve greater success. Concurrently, the school district began implementing reading skills across content areas at the secondary level and the author was introduced to numerous research-supported strategies to help develop reading skills among secondary students including identifying the main idea(s), connecting content to prior knowledge or background experience, and summarizing the text.

RRCU was designed to address the needs of both students and teachers. The strategy supplies the teacher with the standard being addressed (both the state standard and the Common Core Standard for Scientific Literacy), an appropriate and relevant informational text passage, and student activities supported by research as effective (Karpicke and Blunt, 2011; Storm, Bjork and Storm, 2010; Karpicke and Roediger, 2007; Ness, 2007; National Reading Panel, 2000; Sweet, 2000). Students benefit by having a structured mechanism for improving content knowledge and reading skill (Sweet, 2000). Additionally, since the articles tie in to the “real world” and often include unusual or funny science connections, students may develop a greater interest and/or motivation for

science which has also been shown to improve student achievement in science (House, 2008). The RRCU instructional strategy addresses two primary barriers to student achievement on standardized science tests: lack of content knowledge and poor reading skill or comprehension of informational text.

RRCU builds students' content knowledge by addressing NGSSSS specific to the course of study through the careful selection of articles. Articles must be current (within the last 5 years, but often within 2 years), interesting to students (unusual, curious, funny, etc.), not more than 800 words, at an appropriate level of text complexity for the students and their grade level, and clearly support the content of a required/tested state standard. Passage length is capped at 800 words retaining passage on the front side of a single page to support the retrieval-practice portion of the module. The method used to facilitate learning is the retrieval-practice study technique whereby students read the article and then without returning to the article write down everything they can remember reading. This technique has been shown to be more effective than just reading, repeated reading, or concept-mapping of the article (Karpicke & Blunt, 2011).

RRCU develops students' reading skill and comprehension by teaching them specific strategies to comprehend informational text by first identifying the main ideas, making connections to previous knowledge (also building content knowledge) and summarizing the text or passage. Moreover, RRCU is a repeated intervention permitting students numerous opportunities to practice reading strategies in a real and relevant manner. Perhaps most powerful, teachers can use RRCU as a formative assessment of

student progress and understanding. Teachers can use student answers and resulting class dialogue to drive future instruction.

The Role of Knowledge and Reading Skill in Science Achievement

“A learner’s existing knowledge has a large impact on knowledge acquisition (O’Reilly & McNamara, 2007).” Essentially, knowledge is the foundation upon which new information is comprehended and learned. According to Pressly et al. (1992) new information that is easily integrated with existing knowledge is remembered better and students with high domain knowledge are more likely to remember the main ideas of informational text (Spilich et al., 1979). The RRCU intervention is designed to increase domain knowledge through connections to prior knowledge and in turn developing a larger background knowledge-base for future learning. Students enter their courses with different reading skill levels and researchers have argued that the key difference between a skilled reader and a less skilled reader is their ability to implement reading strategies and knowledge in effective ways (Bereiter & Bird, 1985). One goal of the RCCU intervention is to teach students effective reading strategies and provide repeated opportunities for practice and mastery.

Purpose of the Study

The aim of this exploratory mixed-methods study is to investigate the impact of a reading skills instructional strategy intervention, RRCU, on student achievement among high school science students. The instructional strategy aligns with the new Common Core Standards for scientific literacy and the Florida State Next Generation Sunshine State Science Standards. Other researchers have examined the correlation between

student reading skill and achievement on science content knowledge tests (Visone, 2009), investigated effective reading strategies for improving reading skill, and explored the relationship among cognitive ability, reading skill and science achievement (O'Reilly & McNamara, 2007).

In this study, the author examined the impact of a reading intervention designed by the author that incorporates a number of research-based strategies for improving reading and learning including identifying main points in informational text (Armstrong & Armbruster, 1991), summarizing informational text (Zimmerman, 2011), connecting text to prior knowledge and/or background experience (Sweet, 2000) and the retrieval-practice studying technique (Karpicke & Blunt, 2011). Further, this intervention included the use of these strategies on informational text passages selected for their alignment to the Florida State Sunshine State Science Standards, the Common Core Standards for Scientific Literacy and student interest.

Research Questions

- I. Does reading level predict achievement on district benchmark test scores of secondary students in life science courses?
- II. Does the Read, Retrieve, Connect and Use intervention improve academic achievement in life science at the secondary school level?
- III. Does the Read, Retrieve, Connect and Use intervention improve academic achievement in reading at the secondary level?
- IV. How do teachers implement Read, Retrieve, Connect and Use in their classrooms?

Rationale of the Study

Two identified barriers to student success on standardized science exams are lack of content knowledge and poor literacy skills, specifically reading comprehension of informational text (O'Reilly & McNamara, 2007; Visone, 2009). Given the emphasis of standardized testing under both NCLB and RttT as part of wider educational reforms, it is critical that successful interventions are identified to promote student achievement in science. Such interventions are likely to require addressing both the content knowledge and literacy skills of students. The intervention designed for this study links state standards and the Common Core Standards for scientific literacy through informational text passages and research-based reading comprehension strategies including linking textual information to prior knowledge, summarization of text, and identification of key ideas and the retrieval-practice study technique.

To increase student achievement on district benchmark tests, and by extension state and national tests, it is necessary to improve student content knowledge and to improve student reading skill. The intervention, Read, Retrieve, Connect and Use (RRCU), is designed to promote content knowledge by linking informational text passages to the Florida Sunshine State Science Standards and the Common Core Standards for Scientific Literacy. The informational text passages were pulled from well-known science publications such as Scientific American and Science Daily. Passages were selected based on both alignment to curriculum standards and potential interest to students, for example, an article selected to address a standard on enzyme function discusses research on a bacterium that possesses a special enzyme to digest caffeine as its main food source. The RRCU intervention requires students to engage in the retrieval-

practice studying technique which has been shown to improve learning and retention of content (Karpicke & Blunt, 2011).

To increase student reading skill and comprehension of informational text, the RRCU intervention employs research-based reading strategies. These strategies include identifying the main idea(s) of the passage, connecting the text to prior knowledge/background experience, and summarizing the text. The National Reading Panel (2000) recommends the use of these evidenced-based strategies. The aim is to build reading capacity through the content area by having students engage in effective reading strategies without taking time away from required course content.

Assumptions

1. District benchmarks tests accurately assess student content knowledge in science.
2. FCAT Reading scores provide a reliable assessment of student reading skill.
3. Participating teachers possess the knowledge and skills necessary to appropriately implement the intervention as directed.

Scope and Delimitations

The sample population was limited to a single, mid-size school district in South Florida. Two high schools took part in the study and the teachers participated voluntarily. Therefore, there could be a school and/or teacher effect. RRCU can be implemented in a variety of ways (see appendix B) and teachers were encouraged to use RRCU as they deemed most appropriate for their students. However, this means that there was not a uniform approach and the study cannot reveal connections between student achievement and mechanisms of implementation.

High school students were enrolled in either a Biology I or Honors Biology I course. The student subjects were highly diverse by both racial and socioeconomic group. Results should be generalizable to similar populations but not necessarily to students, schools or districts that vary significantly from the sample population of this study.

Definition of Terms

Terms pertinent to this study include:

Content knowledge is defined as that knowledge specific to the course or topic and defined by the standards for that grade level or course (Gonzales, 2001).

Informational text is defined as text that addresses science domain content knowledge using scientific discourse (Romance & Vitale, 2011). Such text should incorporate scientific terminology and model the process of scientific thinking and reasoning.

Reading skill is defined as “the ability to develop a coherent representation of the text that matches the intended message to the reader (O’Reilly & McNamara, 2007).”

Read, Retrieve, Connect & Use is an instructional strategy designed to connect core scientific content with evidenced-based reading strategies. RRCU is aligned with both the Common Core Standards in Scientific Literacy and the Florida Next Generation Sunshine State Science Standards (Monahan, 2012).

Science achievement is defined as student performance on standardized tests of science such as TIMSS, PISA, NAEP, FCAT or district benchmark exams but may also include student course grades.

Scientific Literacy is defined as:

an individual's scientific knowledge and use of that knowledge to identify questions, to acquire new knowledge, to explain scientific phenomena, and to draw evidence based conclusions about science-related issues; understanding of the characteristics features of science as a form of human knowledge and inquiry; awareness of how science and technology shape our material, intellectual, and cultural environments; and willingness to engage in science-related issues, and with ideas of science, as a reflective citizen (Highlights from PISA, 2009).

CHAPTER 2: LITERATURE REVIEW

Introduction

The Organisation for Economic Co-operation and Development (OECD) identified the economic boom of the late 1990's, as driven by scientific and technological advances (The Observer, 2000). The organization also indicated that science, technology and innovation are the keys to improving economic performance and social well-being. Therefore governments must put in place effective policies to foster a supportive climate for growth in these areas.

We have heard these sentiments before, in 1983, the National Commission on Excellence in Education published *A Nation At Risk*. They indicated American students were being out-competed by our international counterparts and without immediate and dramatic improvement dire economic consequences were predicted. In 2008, U.S. political leaders met at Princeton University to call for a renewal in America's commitment to science and technology. Then Speaker of the House, Nancy Pelosi pledged to support the effort by saying, "We stand by this as the most important investment that we can make in health and education and energy independence, job creation and the defense of America" (MacPherson, 2011). And most recently, President Barack Obama indicated it is essential for American students to move from the middle to the top on international assessments (whitehouse.gov, 2010).

Leaders from around the world recognize the importance of science in society from an economic, educational and social perspective. Countries like Japan, Finland,

Singapore, New Zealand, and Korea have undertaken large-scale initiatives to improve science, technology, engineering and mathematics (The Observer, 2000) with resulting high scores on international assessments. Yet, the United States has not demonstrated progress in science achievement as evidenced by scores on the Programme for International Assessment (PISA) and the Trends in Mathematics and Science Study (TIMSS) calling into question the future of science, technology, innovation and economic prosperity in the United States.

According to the U.S. Department of Education, eighty-two percent of twelfth graders performed below the proficient level on the National Assessment of Educational Progress science test in 2000 (Ed.gov, 2004). Moreover, student performance decreases over time in the system with fourth graders significantly outperforming twelfth graders in a longitudinal study. No Child Left Behind (NCLB) attempted to improve the quality of science education and student performance in science by funding partnerships between schools districts and universities, fiscally rewarding states for increasing the number of students participating in advanced science courses, emphasizing the use of research-based teaching methods, and instituting testing at least three times across the K12 spectrum (Ed.gov, 2004).

Although NCLB was passed into law in 2001 with lofty goals for improving student achievement in science, the bar has not been reached, as U.S. performance on state, national and international assessments remains stagnant (references). Since this study aims to investigate a mechanism for improving science achievement this literature review will address several critical issues. First, I will discuss scientific literacy both in

terms of what we mean by scientific literacy and the current status of science achievement in the United States. Second, I will examine standardized testing in science and discuss what exactly is being measured on science assessments and the resulting difficulty in obtaining valid science achievement scores. Third, I will discuss some of the research on building reading skill and comprehension in general and then specifically within the science content area. Lastly, I will explain how the Read, Retrieve, Connect and Use (RRCU) strategy combines well-researched mechanisms for improving learning and reading to support and improve science achievement.

Science and Scientific Literacy

Defining either science or scientific literacy proves challenging as there are as many definitions as there are authors. The most basic definition of literacy is the ability to read and write (Merriam-Webster). Both science and scientific literacy add layers and complexity to that definition. Students need to be able to read and write about science, to know certain science content, use scientific knowledge to make sound decisions, and to be able to critically analyze scientific content in popular media (Fang and Wei, 2010; Hand et. al., 2003; Norris and Phillips, 2003), but these do not fit under the single umbrella of either science or scientific literacy.

The term “scientific literacy” has been bandied about since the 1940’s but really took hold in the late 1950’s with Paul DeHart Hurd’s article, “Science Literacy: Its Meaning for American Schools.” Hurd argued that science education should consist in large part in preparing students as citizens because few decisions (economic, political, or personal) can be made without taking into account the science and technology involved

(Hurd, 1958). Despite this cogent argument, most school science programs focus on the content and methodology required for the preparation of careers in science (Bybee, 2009).

Maienschein (1998) argued for two distinct items, *science* literacy and *scientific* literacy. Science literacy would include scientific or technical knowledge or what could be described as textbook science (Berger, 2002). Scientific literacy would emphasize ways of knowing and thinking critically about the natural world. The problem for the U.S. lies in the contradiction between the two because although policy-makers often speak of scientific literacy, national and state tests are assessing science literacy. Compounding the problem is that the PISA exam, using Maienschien's definitions measures scientific literacy more than science literacy. And it is the PISA results that seem to arouse the most reaction from political leaders, educational experts and society alike.

Norris and Phillips (2003) defined two distinct forms of literacy. One is the ability to read and write and the other being the knowledge, learning and education specific to science. Reading and writing is identified as the fundamental sense of literacy while being knowledgeable, learned, and educated in science is the derived sense. This is an important concept because it illuminates the inextricable connection between the ability to read and write and the ability to know, do and think about science. Norris and Phillips (2003) describe the relationship as:

The relationship is a constitutive one, wherein reading and writing are constitutive parts of science. Constitutive relationships define the necessities because the

constituents are essential elements of the whole. Remove a constituent, and the whole goes with it. (p. 226)

Therefore, students who cannot read and write at an appropriate level will struggle to build either science or scientific literacy. If the goal is to develop either science or scientific literate students we must address their basic literacy skills.

The Common Core Standards, adopted by the majority of states, outlined a framework for scientific literacy focused on applying literacy skills (reading and writing) to scientific, technical, and informational texts to better prepare students with the required skills for college or careers. According to Casteel and Isom (1994) students with literacy inefficiencies are likely to have difficulties in acquiring science information, understanding scientific procedures, and conducting experiments. They also point out that science texts often have large numbers of unfamiliar terms adding to the difficulty in developing literacy in this content area.

The Common Core Standards for Scientific Literacy (see Table 2-1) in grades 9-10 include standards that address domain-specific words, following complex multi-step procedures, and acquiring and analyzing science information.

Table 2-1 Common Core Standards for Literacy in Science

RST.9-10.1. Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.

RST.9-10.2. Determine the central ideas or conclusions of a text; trace the text's explanation or depiction of a complex process, phenomenon, or concept; provide an accurate summary of the text.

RST.9-10.3. Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.

RST.9-10.4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades 9–10 texts and topics*.

RST.9-10.5. Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., *force, friction, reaction force, energy*).

RST.9-10.6. Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text, defining the question the author seeks to address.

RST.9-10.7. 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.

RST.9-10.8. Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem.

RST.9-10.9. Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts.

RST.9-10.10. By the end of grade 10, read and comprehend science/technical texts in the *grades 9–10 text complexity band independently and proficiently*.

Note. Adapted from “Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science and Technical Subjects,” by the Common Core State Standards Initiative, 2011.

However, the Common Core does not identify content knowledge or specific science skills that students should know or be able to do. The Common Core standards address Norris and Phillips' fundamental sense of literacy but educators must combine these standards with content standards to facilitate the derived sense of science literacy.

In 1996, the National Research Council (NRC) published the *National Science Education Standards* and addressed numerous aspects of science education including teaching, assessment, and science content. However, there was no universal adoption of these science standards by the states and so most states continued to develop and use their own standards. The NRC has once again taken on the task of developing a new set of science standards but it is not part of the overall Common Core initiative and it remains to be seen whether all states will sign on when the standards are available in 2012 or 2013. The goal of the project is for students to have a deeper and more conceptual understanding of science grounded in thinking and reasoning skills (nextgenscience.org). While these new science standards should provide clear guidelines for science content there will be a need to connect them with the Common Core Standards for Scientific Literacy.

The teaching and learning strategy under study, RRCU, connects state science standards (Florida) with the Common Core Standards for Scientific Literacy. The goal of RRCU is to develop science content knowledge and build basic literacy skills for secondary students. This addresses both the fundamental and derived sense of science literacy as described by Norris and Phillips (2003). So what of scientific literacy – the ability to apply scientific knowledge and critically analyze science in the media? RRCU

addresses this issue as well by incorporating articles on current research that are interesting, authentic, and relevant to both course content (science literacy) and to the student (scientific literacy). RRCU promotes critical thinking, discussion, analysis and drawing explicit connections between science content and the “real world.” Moreover, RRCU can be modified to fit other state standards or future national standards while still forming a bridge with the Common Core Standards for Scientific Literacy. Merging literacy and science processes will benefit students by increasing their knowledge of science and their proficiency in reading and communicating (Castell and Isom, 1994).

Science Achievement

International Comparisons

Policy makers, educators and the general public have developed an interest in statistics that enable comparisons among countries. The particular interest in education statistics may stem from the alleged link between educational performance and economic prosperity. Two prominent international assessments that examine student achievement in science include the Programme for International Assessment (PISA) and the Trends in Mathematics and Science Study (TIMSS). It is not entirely possible to directly compare PISA and TIMSS results given that each exam assesses a different piece of the science domain. PISA focuses on scientific literacy defined as, “the capacity to use scientific knowledge, to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity” (PISA 2003 Assessment Framework). While TIMSS has a curriculum focus, assessing the topics or concepts students are expected to learn and their

cognitive skill development in terms of knowing, applying and reasoning (Highlights from TIMSS, 2007). Additionally, participating countries vary between the assessments.

In 2009, U.S. students earned an average score of 502 which was not measurably different from the Organization for Economic Co-operation and Development (OECD) average score of 501. Of the participating OECD countries, 12 earned higher scores than the U.S. and 9 earned lower scores with 12 scoring in the same range. The top scoring countries included Finland, Japan, Korea, New Zealand, Canada, Estonia, Australia, Netherlands, Germany, Switzerland, United Kingdom, and Slovenia. (Highlights from PISA, 2009) The 2009 scores were an improvement of the 2006 scores in which U.S. students earned an average score (489) significantly below the OECD average (PISA: Science Competencies for Tomorrow's World, 2006).

The TIMSS science assessment has undergone some changes over time making it difficult to compare results across testing. In 1999, the U.S. earned an average score of 502 which exceeded the participating country average of 487, but it still resulted in a 19th ranking similar to the first administration of the exam in 1995. Higher in the rankings were Singapore, Korea, Japan, Canada, Finland, Australia and the Russian Federation among others. The U.S. posted gains in the 2003 administration of TIMSS with both fourth and eighth graders scoring above the international average, however fourth grade scores actually declined from the previous administration while eighth grade scores rose 12 points. The most recent TIMSS assessment in 2007 found the U.S. scoring higher than the average but not markedly improving from prior years (Highlights from TIMSS, 2007). A conservative analysis of U.S. student test scores on international assessments

would indicate that the U.S. is at best, stagnant and at worst falling behind other countries.

National Assessment of Educational Progress

The National Assessment of Educational Progress (NAEP) in Science underwent an overhaul in 2009 in order to align with the recent publication of the National Education Standards and Benchmarks for Scientific Literacy produced by the National Research Council and the American Association for the Advancement of Science. The 2009 framework is designed to measure science content and science practices. Science content assesses knowledge in the three areas of Physical Science, Life Science, and Earth and Space Science reflecting the concepts students are typically exposed to through a K-12 curriculum. Science practices examines what students are able to do with the science content including identifying science principles underlying each of the three areas, using science principles to make predictions and observations, using scientific inquiry to design, critique, evaluate or analyze scientific investigations and experiments, and to use technological design to solve real world problems and anticipate the impact of design decisions. (Nation's Report Card)

U.S. students performed terribly on the 2009 NAEP in science with 21% of twelfth graders scoring at or above proficient. Of that 21%, just 1% earned an "advanced" score demonstrating superior performance. Scores were little better among eighth and fourth graders, with just 30% and 34% respectively, earning a score of proficient or higher.

While it may be tempting to blame the low scores on the revision of the test, scores were not much better in previous administrations. In fact, scores on the NAEP have mostly been falling. In 1996, 21% of twelfth graders earned scores at or above proficient, by 2005 it had dropped to 18%. Eighth graders were at 29% rose to 30% and by 2005 had returned to 29%. Fourth graders have demonstrated mixed results since 1996 starting at 28%, dropping to 27% and by 2005 reaching 29%. These scores mirror reading scores on the NAEP, and David Winick, chairman of the National Assessment Governing Board which sets policy for the NAEP said, "If the kids can't read...they're going to have a hard time in science."

Florida Comprehensive Achievement Test

The Florida Comprehensive Assessment Test (FCAT) is designed to measure student achievement of selected benchmarks from the state standards (currently the Next Generation Sunshine State Standards) in mathematics, reading, science and writing. FCAT Science was first implemented in 2003 in grades 5, 8, 10 (2003 and 2004) and 11 (2005-2011) in response to the requirements of No Child Left Behind. The FCAT Science has undergone multiple revisions, both in scoring and design) over the years since initial implementation, so it is questionable whether conclusions can be drawn across years, but scores have steadily risen.

In 2003, just 28% of fifth graders were scoring proficient or better and by 2011 51% of fifth graders were scoring proficient or better. Among eighth graders in 2003 28% scored proficient or better and by 2011 46% of eighth graders earned a proficient or better score. In high school, 29% scored proficient or higher in 2003 and by 2011 40%

earned proficient or better scores. It should be noted that the open-response style questions were removed from the more recent administrations of the test leaving only multiple choice style questions. (www.fldoe.org)

The school district involved with this study has consistently scored below state averages in science. In 2011, 43% of eighth grade students scored proficient or better compared to 46% in the state. Just 33% of eleventh grade students scored proficient or better compared to the state average of 40%. Districts to the north and south surpassed the state average in both groups.

Science Achievement Gap

One of the stated goals of NCLB was to improve academic standards and achievement for all students. NCLB may not have closed the achievement gap, but it did shine a light on the gap and force schools and teachers to rethink their approach for struggling students. Ironically, NCLB has improved student achievement for all students, unfortunately that also means the achievement gap has been retained and with the increase in testing there is even more data to reveal the gap. The achievement gap is a significant challenge for schools. Schools are struggling to meet performance targets required under NCLB and can face sanctions if even a single sub-group misses a prescribed target. In Florida, schools are assigned letter grades based in large part on student performance on the FCAT. Many schools have not found success in getting all subgroups to meet performance targets (Subgroup achievement and gap trends: Florida, 2010)..

What is meant by achievement gap? The common definition is the differences in scores on state or national achievement tests between various demographic groups (Anderson, Elliott & Fowler, 2007). The most commonly discussed gap is that between white students and Black students, but it has become evident that Latino students must also be included in this discussion. Also, the achievement gap can be viewed from a socioeconomic standpoint, although even accounting for socioeconomic status, whites outperform both Blacks and Latinos (Rothstein, 2004).

Results of the NAEP Science indicate little improvement in test scores since 1996. Blacks and Latinos in 4th grade have demonstrated a slight increase in scores but the gap remains unchanged by 12th grade (Nation's Report Card, 2005). On the 2009 NAEP Science white students earned an average score of 161, African Americans earned 126 and Latinos earned 136 points. The average score is 150 points and just 31% of all students score proficient or better. What does this mean? In eighth grade just 8% of African American and 12% of Latino students score proficient or better in Science. Similar results are seen in both Reading and Mathematics.

The Center on Education Policy (2010) examined results on state tests and the NAEP since 2002 and identified four main conclusions. One, achievement gaps are wide and persistent. Two, all student groups are making gains on reading and math tests, but that is not necessarily narrowing the gap (lower-achieving groups must make gains at a greater rate than the higher-achieving group). Three, gap trends vary across states and groups particularly depending on the indicator used. And lastly, it will take many years to close most gaps in student achievement.

In Florida, a state with a typical gap size between African-American and white students, it would take 28 years to close the gap at the current rate (Subgroup Achievement and Gap Trends, Florida, 2010). The gap in reading is wide. While 66% of white students scored proficient or better in 2009 on FCAT Reading, just 34% of African American students scored proficient or better and 47% of Latino students. On Science FCAT, 20% of African Americans and 34% of Latinos scored proficient or better compared to 52% of white students in 11th grade (Florida Department of Education, 2011).

How can the gap be closed? Closing the gap requires improving the performance of lower-achieving groups. Studies by Visone (2009) and O'Reilly and McNamara (2007) indicate there is a correlation between reading scores and science scores, in that reading scores can be used as predictors for science scores. Cromley (2009) analyzed PISA scores and determined that the knowledge and skills that drive reading achievement also drive science achievement. Data also indicate that all students perform better on science tests when read the questions aloud (Meloy, Deville, & Frisbie, 2000), indicating reading is an obstacle to revealing student knowledge of science. One strategy for improving student achievement in science is to develop stronger reading skills through the explicit teaching of reading strategies embedded in science course content. This would help to ensure that what we are measuring with standardized science tests is science content knowledge and/or scientific literacy and not reading skill.

Standardized Science Testing

Under NCLB and RttT, students are being tested more than ever before and test scores are being used in a myriad of ways including determining student progression, student graduation, school grades, and teacher pay. The question to be asked is, are tests measuring what we think they are measuring? Visone (2010) argues that science assessment scores may be greatly influenced by student reading proficiency in that poor reading skill can act as an impediment to demonstrating success on a science assessment. This conclusion is supported by a number of other studies.

Meloy, Deville, & Frisbie, (2000) assessed the impact of a read aloud accommodation on students with a learning disability (LD) in reading. The design of the study included an LD group exposed to the read aloud accommodation, an LD control group, a non-LD group exposed to the accommodation, and a non-LD control group. Not only did the read aloud accommodation positively impact LD student test scores across subject areas including math and science but the non-LD group also benefited from the read aloud accommodation. The authors concluded that the read aloud accommodation shifted the construct being measured from reading skill to content knowledge.

An analysis of test item read-ability by Hewitt and Homan (2004) indicated that items with a high (more difficult) readability value resulted in more students missing (incorrectly answering) that item. Studies by Abedi and Lord (2001, 2004) indicated a relationship between test item readability level and student scores. The researchers decreased the readability level (but not the content or skill being assessed) of test items on a math assessment and student scores increased. Similar findings were revealed when

researchers examined sentence complexity on the TIMSS. Dempster and Reddy (2007) found that as the degree of sentence complexity increased students were more likely to randomly guess.

O'Reilly and McNamara (2007) examined the impact of science knowledge, reading skill, and reading strategy knowledge on science achievement. Science achievement was measured three ways: students' comprehension of a science passage, grade in science course, and student scores on state science exams. The authors found that the cognitive variables (science knowledge, reading skills, and knowledge of reading strategies) predicted all three measures of science achievement.

Together these studies indicate that reading skill plays a critical role in student assessment at a time when standardized testing is on the rise. Clearly, reading comprehension issues may undermine assessments of content knowledge and compromise test validity (AERA et al., 1999; AERA, 2000).

Teaching Reading In Science

Strong literacy skills are required to prepare students for higher education, careers, and life in a rapidly evolving technology-driven information age. Unfortunately, the NAEP reveals that the majority of students entering high school are not able to read at grade level and a quarter of those are reading below a basic level (U.S. Department of Education, 2009). Improving reading scores has proven to be a tough obstacle for educators to overcome despite the emphasis placed on reading due to NCLB's requirement that every student be reading on grade level by 2014. Results of intervention strategies have not been uplifting. A recent experimental study of Project CRISS

conducted by the U.S. Department of Education (2011) revealed that despite a significant investment of time, funding and training, there was no statistically significant impact on the reading comprehension of students exposed to CRISS strategies.

A broad experimental study by James-Burdumy et. al. (2009) investigated the impact of several reading intervention programs including Project CRISS, ReadAbout, Read for Real, and Reading for Knowledge. Students were measured by scores on the Group Reading Assessment and Diagnostic Evaluation and a social studies or science comprehension assessment developed by the Educational Testing Service. Students in the experimental groups did not score higher in reading comprehension and when data for all four groups were combined, the intervention group students scored lower than control group students. If these large-scale and often costly reading programs fail to deliver results, what can we do to improve reading? And if students cannot read at grade-level, how can we expect to gather accurate or useful data on student learning from content-knowledge assessments? It is imperative that we improve student reading ability if we want to reveal and measure what students know about science on science assessments.

There is a robust literature on the teaching and learning of reading, but the essential points for this study involve strategies that can be reasonably implemented in a content-specific subject area such as science. So what do we know about reading instruction that might benefit both science teachers and students? According to the National Reading Panel's (2000) meta-analysis of research on reading instruction there are specific strategies that can be used in both vocabulary instruction and text comprehension instruction that benefit students in developing their reading skill. The

panel identified five main methods of teaching vocabulary: explicit instruction, implicit instruction, multimedia methods, capacity methods, and association methods. These findings indicate that specific vocabulary instruction can improve comprehension, vocabulary can be learned incidentally through exposure, and repeated authentic exposure to vocabulary words is important for building reading skill.

The National Reading Panel (2009) also identified eight different procedures for effectively improving reading comprehension. These included (see Table 2-2 for full list) cooperative learning, question answering, and summarization.

Table 2-2. Eight Evidenced-Based Strategies to Improve Reading Comprehension

1. Comprehension monitoring	Reader learns to be aware of his/her understanding and learns procedures to cope with problems
2. Cooperative learning	Readers work together to learn reading strategies
3. Graphic and semantic organizers	Graphical representation of meanings and relationships of ideas
4. Story structure	Reader learns to ask who, what, why, where and when about characters, events and/or plot
5. Question answering	Reader answers questions posed by teacher and is provided feedback on correctness
6. Question generation	Reader generates questions
7. Summarization	Reader attempts to identify and write main ideas of text
8. Multiple-strategy teaching	Reader uses multiple strategies with teacher in an appropriate way

Note. Adapted from National Reading Panel's Recommendations (2000) to improve reading comprehension.

Cooperative learning requires readers to work together to identify and build strategies appropriate to the context of the reading. Question answering requires students to answer questions posed by the teacher regarding the text and the student must be provided feedback on the correctness of their responses. In summarization, the student attempts to

identify and write the main ideas or concepts in a single coherent whole. These three strategies can easily be applied within any content-specific course to support and build reading skills with the added benefit of increasing the student's knowledge of course-specific content.

Tunde Owolabi (2009) argued that science teachers must employ well-informed pedagogical skills to facilitate reading comprehension. In his study, he examined the impact of collaborative learning, multiple intelligences and teacher-led instruction on building reading comprehension in a science class. The data demonstrated a significant impact of using the multiple intelligences method on student achievement. However, the study employed an instrument developed by the researcher and was not included as an appendix leaving it unclear as to whether the test focused on content or reading ability. Also, the author failed to describe how the multiple intelligences method specifically addressed the development of reading skills.

Ness (2007) offered suggestions on how middle and high school teachers in content areas can provide the explicit reading instruction required for students to comprehend the rigorous demands of content-areas textbooks. She argues that content area teachers should emphasize reading and writing practices specific to their subjects. Ness acknowledges that secondary schools in the U.S. tend to focus on breadth over depth in preparation for state tests (increasing in number with NCLB and RttT) which can force literacy instruction to the background in the content-area classroom. This would indicate it could be beneficial for students and teachers if a reading instructional strategy

specifically incorporated assessed material, so that teachers would not feel that they were sacrificing content for reading instruction.

A reading intervention developed by the Center for Research on the Educational Achievement and Teaching of English Language Learners, Quality English and Science Teaching (QuEST), was developed to improve both science knowledge and academic language of middle school English language learners in mixed classrooms. District and state standards were used to set science and literacy goals and the intervention focused on using a hands-on inquiry approach as well as explicit vocabulary instruction and collaborative learning with mixed groups of English language learners and native speakers of English. Results from the Group Reading Assessment and Diagnostic Evaluation (GRADE) assessment showed gains for all students in both science and literacy achievement. The impact was modest but if the strategy were employed for three years it would result in four years of learning (August et. al., 2010). Of note regarding this study, the literacy strategy was an enhancement of more traditional teaching methods, not a complete overhaul, easing implementation at other sites. Also, the method benefited all students, not one group at the expense of another.

Other researchers have also investigated the impact of reading strategies that specifically address core science concepts. Science IDEAS is a cognitive-science-oriented model that integrates reading and writing with in-depth science instruction in the elementary classroom. Students participate in 1.5 – 2 hours of daily science instruction with an additional 30 minutes of instruction in literature. A study by Romance and Vitale (2011) indicate the model can be implemented with fidelity and that the program has a

positive effect on achievement. However, minority status, Title I status, and being male resulted in a negative correlation with achievement. This is particularly concerning given the already existing achievement gap in both reading and science between white and minority students, and high socioeconomic status students with low socioeconomic status students. However, the results do show some promise and the authors suggest that schools might want to invert the current allocations of time to basal reading instruction and content-area instruction in order to better address student achievement in both critical areas.

Pertinent to the current study is the ability of effective reading instruction in developing engaged, knowledgeable, strategic and motivated readers (Sweet, 2000) who in turn are more likely to demonstrate proficiency in both reading and content areas. Unfortunately, research indicates that secondary teachers often possess a poor attitude towards reading instruction and that little time is dedicated to explicitly teaching reading strategies to struggling readers (Ness, 2008; Ness 2009; Ulusoy & Dedeoglu, 2011). This is particularly concerning because many students arrive in high schools without sufficient conceptual prior knowledge to succeed in science courses or the more general capacity to effectively handle text comprehension (van den Broek, 2010) of often rigorous and high-level textbooks. In fact, Kamil (2003) claims 8.7 million fourth through twelfth graders struggle to read their textbooks and that they encounter significant challenges with comprehension.

Yet one study by Ness (2008) found little explicit reading instruction occurring in secondary content-area classrooms. Teachers often admitted students had trouble reading

the text, so the teachers helped them by showing pictures and speaking aloud about the content of the text and relied on multiple presentations of the material to help struggling readers. Ness found teachers were quite adept at teaching to multiple modalities and using heterogeneous grouping, but none of the eight teachers in her study enacted explicit reading instruction to facilitate student learning of content or build reading comprehension.

Similar results were found by Ulusoy and Dedeoglu (2011) in an investigation of teacher practices in grades 1 through 8 for teachers of science. Other teachers (social studies, comprehensive, math, electives) were found to use many of the strategies recommended by the National Reading Panel as highly effective, but science teachers indicated they only sometimes or never used reading strategies in their classroom. The majority of science teachers used didactic techniques, predominantly lecture-based, to cover course content. Interestingly, all participating science teachers acknowledged their students had serious reading and comprehension problems and half of them stated they were not reading and writing teachers.

A second study by Ness (2009) also revealed that science teachers were less likely to employ explicit reading instruction and when they did so they tended to use question answering, analyzing text structure, and summarization of text. This is problematic because as indicated above, students are entering middle and high school without the requisite and necessary reading skills to address the rigorous academic expectations, particularly in science courses. This places an impetus on reading teachers to improve

student reading skill, but surely, it also places an onus on teachers of science to incorporate reading strategies specific to science content.

In summary, we know that incorporating specific reading instructional strategies into science classes improves student achievement in both science and reading. We also know that many secondary teachers, particularly science teachers, do not include specific reading pedagogy nor do they feel obligated to do so despite their acknowledgement that students struggle to read and comprehend science textbooks.

Read, Retrieve, Connect & Use

Read, Retrieve, Connect and Use (RRCU) is a teaching and learning strategy developed by the author for use in her classroom at a highly diverse, urban, Title I high school in response to state and district mandates to improve science achievement scores. RRCU is designed to improve student achievement in science by emphasizing required course content (as indicated by state standards) and developing reading skills specific to informational text. Each RRCU is a single page module that includes an informational text passage, a retrieval activity, and questions designed to support and build reading comprehension. Passages are selected for grade-level appropriateness, interest, and salient connections to course content. Each RRCU focuses on a single core science standard from the Florida NGSSSS and one Common Core Standard for Literacy in Science. RRCU modules are a straight-forward, evidence-based method for increasing reading opportunities in science courses without taking time away from content instruction.

Retrieval Practice

Each RRCU is designed to address two distinct educational issues, science content based on the state standards and reading comprehension. Science content knowledge is addressed through the use of a retrieval practice method. Typically, learning is thought to happen when individuals encode knowledge and experiences but recent research has indicated that the process of information retrieval also produces learning and may be more powerful than an encoding event (Storm, Bjork, & Storm, 2010; Karpicke & Roediger, 2010; Karpicke and Blunt, 2011). Karpicke and Blunt (2011) compared the retrieval practice method with an elaborative study task (concept mapping). In concept mapping, students construct a diagram that represents relationships of content while viewing a piece of text. Retrieval practice requires student to study the text and then recall as much of the information as they can on a free recall test. This is then repeated. The total learning time was matched for both groups.

One week later, participants returned to take a short-answer test on the initial text studied. The questions comprised both conceptual knowledge and inference type questions. Retrieval practice produced the best learning when compared to elaborative learning and extra time reading the text, with a 50% improvement in long-term retention scores. The proportion of ideas produced by the concept map group and recalled in the retrieval group were nearly identical, so this cannot be the source of the learning difference. Also interesting, participants of the retrieval practice group predicted it would be the least beneficial and that repeated studying would produce better results, the opposite of the study results. Of particular interest to this author, the study used science

texts that addressed major concepts in life science such as properties of muscle types and the process of digestion suggesting retrieval practice as an effective means for improving student knowledge and subsequent performance on assessments in science.

A second experiment by Karpicke and Blunt (2011) sought to replicate and extend the initial study. They did so in three ways: using texts with different knowledge structures including enumeration and sequence, examining the effectiveness of the retrieval practice and concept mapping strategy for each student individually, and by assessing long-term learning using two different test formats (short answer questions and creating a concept map without viewing the text). Again, the results on the final short-answer test demonstrated a large benefit to retrieval practice over elaborative learning for both text types. Retrieval practice also resulted in better performance on a final test that required the construction of a concept map. Finally, since students had participated in both retrieval practice and concept mapping, the researchers examined the individual impact of the strategies. Their results indicated 84% of students performed better after retrieval practice than elaborative studying with concept mapping. According to the U.S. Department of Education's What Works Clearinghouse (2011), the study was a well-implemented randomized controlled trial.

RRCU incorporates the use of retrieval practice study to support students in learning content that will be assessed on district, state and national tests. Students read a passage on a core content topic identified through the state standards. After reading the passage, students are given an open-response recall test where they are asked to write down any and all information they can remember from the passage. This activity is then

followed up with several questions designed to cement learning through connecting to background knowledge and to build reading comprehension through the used of evidenced-based strategies.

Building Reading Skill

Educators and researchers have called for an integration of literacy practices and the teaching and learning of science for nearly a decade (Hand et. al., 2003; Norris and Phillips, 2003). Guzzetti and Bang (2011) recognize that there has been shift in viewing science as predominantly a mathematics-based process to a language process. Scientists rely on language through reading, writing, and talking about science which are fundamental to the process of doing and communicating science. Unfortunately, many secondary teachers still view science as an empirical or practical subject rather than a language-based process. RRCU refocuses teachers and students on using informational text to develop content knowledge and build reading comprehension skills. Literacy strategies are embedded into the process of teaching science instead of being added on to or replacing science content.

Combined literacy-based and content instruction can support and extend students' scientific knowledge (Casteel and Isom, 1994) and also improve student interest and motivation in science (Fang & Wei, 2010; Guzzetti & Bang, 2011). Fang and Wei's (2010) study examined the impact of explicit reading instruction infused into an inquiry-based science curriculum. Reading strategies such as predicting, questioning, morphemic analysis, and paraphrasing were taught on a 1-2 week cycle. The selected strategies were selected from a review of the literature including the National Reading Panel's

recommendations for effective reading instruction. The experimental group significantly outperformed the control group in both the fundamental and derived senses of science literacy. RRCU incorporates similar reading strategies and is also conducted on a bi-weekly basis.

Guzzetti and Bang (2011) investigated the effects of a literacy-based approach to teaching secondary chemistry through a forensics science unit. Students in both groups were pre and post-tested on the same content standards. The literacy-based strategy incorporated a range of texts as reading activities, required students to author their own texts, and to maintain a reflective journal. The control group students were exposed to the district's extant curriculum covering the same standards as the forensics unit. Post-tests revealed a significant difference between groups with the experimental group outperforming the control group. Additionally, students in the experimental group reported more positive attitudes towards science and careers in science than members of the control group.

While this study supports embedding literacy-based instruction it should be noted that there was also a dramatic difference, not just in the instructional strategy, but also in the framework of presentation between groups. It may be that the forensics framework resulted in improved student achievement, not the literacy-based instruction. RRCU attempts to provide interesting frameworks for instruction and literacy-based instruction.

Each RRCU consists of a 300-500 word article selected to meet three criteria. One, the passage must directly address a Florida Next Generation Sunshine State Science Standard. Two, the passage must be grade-level appropriate for the intended student

audience and three, the passage should be on a relevant, authentic and interesting topic for students.

Following the retrieval practice activity, students are asked a series of four questions. Students are permitted to access resources to address these questions and resources may vary by classroom, teacher, or school but would commonly include a textbook and perhaps internet access by computer or other device.

The first question specifically addresses the NGSSSS identified at the beginning of the document and upon which the article/passage was selected. The second question is designed to guide the student into making a connection between the content standard and information provided in the passage. The third question requires students to use information from the passage and connect it to the science standard of interest. The last question requires students to summarize key ideas or concepts from the passage. Questions three and four are written to align with the Common Core Standards for Scientific Literacy while still meeting the recommendations of the National Reading Panel's (2000) research findings on effective strategies for building reading comprehension. As described above, effective strategies for supporting the development of reading comprehension include summarization, implicit and repeated exposure to vocabulary, and question answering.

Summary

Student performance on international, national, and state standardized science tests is lackluster. Compounding the problem is evidence of a wide gap among the scores of African Americans and Latinos with white students despite the intentions of No Child

Left Behind and Race to the Top. These two issues require action and research indicates that student test scores in science may be a greater reflection of their reading skill than their science content knowledge (Visone, 2009; O'Reilly & McNamara, 2007).

Therefore, to improve student academic achievement in science, it is necessary to improve student reading skill. Improving students' reading skills should have two benefits. One, they will be better able to understand the questions being asked on standardized science tests. Two, the development of stronger reading skills will enable students to learn more science content.

Science content is a component of science and/or scientific literacy. Both terms, science literacy and scientific literacy, rest on a foundation of content knowledge and basic literacy skills (Norris & Phillips, 2003). From the literature, a significant difference can be identified between the terms. Scientific literacy indicates an ability to use one's knowledge of science in everyday life to make good decisions as an individual and as a member of a larger society (Maienschein, 1998). Science literacy leans more towards specific content that would be required of those preparing for careers in science (Berger, 2002). What is most important for this study, is that both science and scientific literacy require fundamental literacy skills and awareness of what is science and how science is done. Read, Retrieve, Connect & Use is designed to address both sets of knowledge.

There is a link between reading scores and science scores. Data indicate that students with higher reading scores also score higher on science tests (Cromley, 2009). FCAT data indicate that African-American and Latino students consistently have lower reading and science scores than white students (Florida Department of Education, 2011).

To close this achievement gap will require an improvement in both reading skill and science content knowledge.

The National Reading Panel (2000) conducted a meta-analysis of the research on reading strategies and based on the findings identified a series of recommended strategies. Some of those strategies include teacher questioning, implicit exposure to vocabulary, repeated opportunities to read informational text, connecting to prior knowledge and summarizing key ideas or concepts of text. These skills serve to not only build reading comprehension but are also required for the development of science content knowledge (Casteel & Isom, 1994; Hand et. al., 2003; Norris & Phillips, 2003).

The adoption of the Common Core Standards for English Language Arts by most states will require schools and teachers to implement standards for scientific literacy. These standards will help address the foundational literacy skills (reading and writing) required for science and scientific literacy. However, schools and teachers will also be required to meet state standards (and perhaps national standards in the future) for science content. This creates a need for instructional strategies that embed the required standards of scientific literacy within the required content standards for science.

Read, Retrieve, Connect and Use combines the Florida Next Generation Sunshine State Science Standards and the Common Core Standards for Scientific Literacy with two instructional activities. The first activity is based on the retrieval practice technique that has been shown to be a powerful learning event for students (Karpicke & Blunt, 2011; Karpicke, 2009; Karpicke & Roediger, 2007). This portion of the strategy is designed to build content knowledge directly connected to a state standard.

The second activity is founded upon the recommended reading strategies from the National Reading Panel (2000). An informational text passage is followed with four questions. Each question is designed to connect the Common Core Standard for Scientific Literacy with the NGSSSS using an evidenced-based technique such as connecting to prior knowledge or summarizing key ideas. The intention is to support both the development of science content knowledge and the building of reading comprehension skills to improve academic achievement among secondary life science students.

No Child Left Behind and Race to the Top have resulted in an increased focus on student performance and placed additional value on the role of standardized testing. Lackluster performance on state, national, and international assessments of reading, mathematics and science has fueled reform efforts and partisan rhetoric. Regardless of the politics involved, there is an obligation on the part of educators to improve the quality of their instruction to benefit all students. The literature makes it evident that reading instruction can no longer be isolated from content area instruction.

CHAPTER 3: METHODOLOGY

This chapter presents the methodology used in this study to assess the impact of the Read, Retrieve, Connect and Use instructional strategy on student achievement. It begins with the research questions addressed by the study, followed by an overview of the study's design, a description of the setting, sampling techniques, procedures, description of the instructional strategy being assessed, the instrumentation and ethical considerations.

Purpose and Research Questions

The purpose of this study was to investigate the impact of an instructional strategy designed to improve science content knowledge and build reading skills. The instructional strategy was designed by the author and incorporates a number of research-based strategies for improving reading skill and retaining content knowledge. The first two research questions specifically address the potential impact of the RRCU instructional strategy and were addressed using multiple analysis of variance (MANOVA):

- I. Does the Read, Retrieve, Connect and Use intervention improve academic achievement in life science at the secondary level?
- II. Does the Read, Retrieve, Connect and Use intervention improve academic achievement in reading at the secondary level?

The third research question is designed to formulate context for the first two questions. Since RRCU is designed to improve reading in addition to science content knowledge, it

is necessary to explore the relationship of student reading ability on student achievement in science. It needs to be empirically determined if student reading level impacts science test scores and was analyzed using Pearson's Correlation and Regression Analysis:

III. Does reading level predict achievement on district benchmark test scores of secondary students in life science courses?

The final research question was designed to gather information from teachers that had used the RRCU modules. In order to assess the impact of RRCU, it was important to determine how teachers had implemented the strategy in their classrooms and whether they had done so as suggested, this was accomplished via a semi-structured survey:

IV. How do teachers implement Read, Retrieve, Connect and Use in the classroom?

Research Design

This study was designed to evaluate the impact of the Read, Retrieve, Connect and Use instructional strategy on student achievement as measured by district benchmark tests in science and reading. RRCU is a teacher-designed strategy to improve scientific content knowledge and build literacy skills. Several teachers in the district used RRCU as a part of their classroom instruction.

The research design included three components, a quasi-experimental analysis of the impact of the Read, Retrieve, Connect and Use (RRCU) intervention, an analysis of the predictive value of FCAT reading level on Benchmark Science scores and a qualitative exploration of teacher implementation of RRCU.

Prior to beginning statistical analyses of the data, a normality test was used to determine the likelihood that the data came from a normal distribution, required for most analyses. Descriptive statistics were also generated. These included N, mean, standard deviation, variance, standard error of the mean, median, mode, and range.

The focus of the study is on the impact of RRCU, the independent variable, on student achievement, the dependent variable. Student achievement was measured using district science and reading benchmark tests. However, there are other variables that may impact student achievement such as student reading level, school site, classroom teacher, and/or gender. A multiple analysis of variance (MANOVA) was used to determine the effect of the variables or their interaction on student achievement.

This study includes a single independent variable, which is the RRCU instructional strategy. Using a MANOVA, permits the assessment of the effect of the treatment on multiple dependent variables. In this study, those variables include science and reading scores. Students were given a pre-test and three subsequent tests in each discipline leading to a repeated-measures design. MANOVA can identify effects across the multiple tests. Additionally, MANOVA allows for the examination of the interaction of other variables that might influence science and reading scores other than the treatment such as grade, gender, race, FCAT Reading level, or learning disability status.

To determine if FCAT Reading level predicts student achievement on District Benchmark tests in science Pearson's Correlation Analysis was used to understand which dependent variables correlate and their effects on student scores. To complete the analysis, a Stepwise and Backward Linear Regression Analysis was used to determine if

FCAT Reading or District Benchmark Language Arts tests impact District Benchmark Biology tests and with which a mathematical model can be made to predict student scores.

While the main thrust of the study is on the impact of RRCU on student achievement, it is important to establish context for student scores. Research suggests that many science tests assess student reading ability rather than content knowledge (Visone, 2009). In developing strategies to meet the needs of students, it is necessary to examine whether the core problem in student achievement in regards to science is a deficiency in content knowledge or reading ability.

Participating teachers were interviewed using a semi-structured design to explore how RRCU was implemented and used in their classroom. The purpose of the interview was to tease out differences in implementation that might affect student performance.

Setting

This study was conducted in a mid-size school district in South Florida. The district is highly diverse with a significant number of Title I schools. Surrounding districts consistently earn higher grades from the state, but in recent years, this district has made great strides in improving student achievement. Forward-thinking and innovative leadership has resulted in a data-driven and reflective teaching and learning environment. However, reading and science scores remain low and suggest a need for specific interventions. There are five traditional high schools and one magnet high school in the district. Teachers at two different high schools, one a Title I school, were using RRCU during this study.

Target Population

The target population is high school students enrolled in a Biology course. Biology is offered in either 9th or 10th grade. All of the traditional high schools struggle to achieve high scores on the district science tests. Since the district uses a controlled-choice model within carefully selected zones, the student population of each high school is fairly representative of the district as a whole. Therefore, although this study examined just two schools, it would be expected that results would be generalizable to other similar schools in the district.

Sampling Plan and Procedure

This was a quasi-experimental study because the group assignment was not random but rather dependent on teacher use of RRCU. Student benchmark and FCAT scores of teachers using RRCU served as the experimental group. Student benchmark and FCAT scores of classroom teachers who did not use RRCU served as the control group. Teacher use of RRCU was determined through site supervisors familiar with instructional strategies employed by their teachers and confirmed with a survey. Such convenience sampling can reduce the likelihood of obtaining a representative sample of the student population. However, the sample size was large, encompassing the overwhelming majority of students enrolled in a biology course at both schools. A fully experimental study would have randomly assigned the RRCU instructional strategy to teachers in an effort to eliminate teacher effect on the outcome. As is often the case in educational research, it can be challenging to implement wholly experimental studies due to institutional and cultural factors.

All teachers of Biology are expected to align their instruction with the district scope and sequence for the course. The scope and sequence identifies which benchmarks from the Next Generation Sunshine State Science Standards should be taught in each quarter. The district assesses student learning of the benchmarks at the end of each quarter. There is a pre-test at the beginning of the school year and the 3rd quarter district benchmark test can be considered a post-test since it is cumulative of all standards to date on the scope and sequence.

The Read, Retrieve, Connect and Use modules focus on key standards that are either foundational to the study and understanding of biology and/or have been repeatedly tested on FCAT Science. Each quarter typically includes 8 -14 standards identified in the scope and sequence. RRCU typically addresses between 3 – 5 standards in each quarter. In addition to addressing specific science content, the intervention incorporates informational text and literacy strategies linked to the Common Core Standards for Literacy in Science.

The RRCU instructional strategy consisted of twelve modules each addressing a single Next Generation Sunshine State Science Standard from the district scope and sequence for Biology and a single Common Core Standard for Literacy in Science. The standards are identified at the beginning of the module followed by an informational text passage addressing the science content standard. Text passages were selected based on a clear connection to the standard, incorporation of current research, use of appropriate scientific vocabulary, and likelihood of being interesting to adolescents. While each article was selected to support a specific content standard, typically, related standards

were also addressed permitting each article to be used by teachers as a starting point for class discussion.

Karpicke and Blunt's (2011) retrieval-practice study technique is used to foster a learning event to improve student retention of content. This is followed by four questions. The first question addresses the specific content standard under study or review. Question two serves to guide students in making connections between the content standard and the content of the informational text passage. The third question requires students to access prior knowledge and make a connection between the content standard and the information provided in the text passage. The final question employs a research-based literacy strategy recommended by the National Reading Panel (2000) to meet a Common Core Standards for Literacy in Science.

Supervisors at both school sites were provided with the RRCU modules and asked to share them with their teachers with a brief overview of how the modules might be used in the classroom. See Appendix A for samples of each module and Appendix B for the accompanying documents provided to supervisors and teachers.

The researcher obtained student data, including scores on all district benchmark tests in biology and reading (for the current academic year) and most recent FCAT reading score for students in classrooms using RRCU and for students in classrooms not using RRCU.

Again, the main purpose of the study was to determine if RRCU is an effective intervention strategy for improving student learning in science and reading as measured by district benchmark scores. However, there may be other variables that impact student

scores including school site, classroom teacher, reading level, or gender. These issues justify the use of a MANOVA to reveal which variables or interaction of variables had an effect on student achievement.

While it may be logical to assume that reading level may correlate or even be predictive of science test scores, there is little empirical data on the topic. Therefore, a regression analysis was performed to determine if FCAT Reading score is predictive of science benchmark scores. This is important since part of RRCU is designed to build literacy skills. If FCAT reading level is predictive of science benchmark scores, will RRCU ameliorate those findings?

At the conclusion of the study, the researcher conducted a semi-structured interview to explore implementation of RRCU across classrooms. The interviews focused on identifying how teachers used RRCU in their classrooms and their perceptions of RRCU as an effective intervention strategy.

Instrumentation

The district began quarterly benchmark testing in an effort to improve student learning and achievement on FCAT. The tests are designed to assess student knowledge of specific benchmarks outlined in the course scope and sequence provided by the district. A pre-test is given at the beginning of the school year and at the end of the first three quarters. The last benchmark test is considered a post-test and is cumulative. Ideally, test results would allow both students and teachers to identify what students know and are able to do and what content or skills need to be retaught/relearned. With recent teacher evaluation systems placing a heavy emphasis on student scores, teachers

(schools and districts) require effective interventions to improve both district benchmark and state assessment scores.

FCAT Reading assesses student learning of the Next Generation Sunshine State Standards in Reading and a passing score is required to earn a standard high school diploma. Given the literature indicating that standardized science tests may measure reading skill more than science content knowledge, student FCAT Reading scores will be used to predict student scores on district benchmark science tests. This is particularly important because RRCU is designed to build literacy skills.

A semi-structured interview was conducted with participating teachers to determine how RRCU was implemented in their classroom. The survey consisted of the following questions:

1. Describe how you implemented Read, Retrieve, Connect and Use in your classroom.
2. Do you feel RRCU was beneficial for your students in terms of improving content knowledge in science and/or building literacy skills?
3. How would you improve the strategy?
4. Would you be interested in attending a workshop to learn more about the science behind RRCU and how to implement the strategy in your classroom?
5. On a scale of 1-5, with 1 being poor and 5 being excellent, how would you rate RRCU as a strategy to improve science content knowledge and build literacy skills?

Depending on teacher response, follow-up questions may have been used for clarification purposes or to gather more information. Follow-up questions included:

- a. How often did you implement RRCU?
- b. Did you use as a class opener, main activity, or closing assignment?
- c. Did students work independently or in groups?
- d. Did you use RRCU as a formative assessment?
- e. Did you find the articles interesting?
- f. Did you feel students found the articles interesting?

Threats to Validity

The greatest threat to validity stems from the non-random nature of the sampling. The experimental group included student data of teachers who have elected to use RRCU as an instructional strategy. It is possible that teachers who opt to use RRCU share other common characteristics that may impact student test scores.

The overall sample size is likely to be relatively small given that RRCU is a new and relatively unknown instructional strategy. Just four teachers across two high schools employed RRCU as a part of their instruction during this study. The number of students did represent a majority at those schools.

There was no available professional development related to the use of RRCU and therefore implementation of the strategy was highly variable across classrooms and schools. How teachers chose to use RRCU as part of their instruction may have affected the efficacy of the intervention.

Schools and/or the district may have been implementing other intervention strategies to improve student achievement. It is not possible to assign causation to the treatment given the design of this study regardless of outcome.

The District Benchmark tests are created among much secrecy and tests are not released. There is no way to independently verify that these tests are accurately and/or adequately assessing the content standards. If the tests are poorly designed they may not be measuring what they are designed to measure. Finally, there is the issue of pre-test effect. If students score well on the pre-test, little room is left for improvement, this can jeopardize external validity.

Ethical Considerations

All identifying information was “washed” from student data after retrieval from the database, Performance Matters maintained by the school district under study.. Teacher names were replaced with an identification number. The purpose of this study was not to evaluate teacher quality but rather to determine whether RRCU is an effective intervention strategy that should be expanded across more classrooms in the district. Therefore, while it is necessary to examine student data by teacher to control for teacher effect, it is not necessary to include teacher names.

CHAPTER 4: RESULTS

The main goal of this study was to assess the effectiveness of the Read, Retrieve, Connect and Use (RRCU) instructional strategy on student achievement. Previous research indicates that students with poor reading skills struggle to perform on assessments of science content knowledge (Visone, 2009; O'Reilly and McNamara, 2007). RRCU was designed to develop literacy skills and science content knowledge to improve student learning. The instructional strategy incorporates research-based strategies for content retention and literacy skills development.

Four research questions were addressed in this study:

- I. Does the Read, Retrieve, Connect and Use intervention improve academic achievement in life science at the secondary level?
- II. Does the Read, Retrieve, Connect and Use intervention improve academic achievement in reading at the secondary level?
- III. Does reading level predict achievement on district benchmark test scores of secondary students in life science courses?
- IV. How do teachers implement Read, Retrieve, Connect and Use in the classroom?

To address these questions a mixed-methods design was used to collect and analyze both quantitative and qualitative data. Student data was collected from two schools and six teachers for 247 students. Data included FCAT Reading score, District Benchmark scores in Language Arts, District Benchmark scores in Biology and demographic data including gender, ethnicity, and teacher (see Appendix C). Student data was divided into two groups based on exposure to the RRCU treatment. Table 4.1 describes the gender of

participants, Table 4.2 describes ethnicity of participants, and Table 4.3 describes the learning status of participants.

Table 4.1 – Study participants by gender in control and treatment group.

Group	Female	Male	Total
Control	48	37	85
RRCU	105	57	162
Total	153	94	247

Table 4.2 – Study participants by ethnicity in control and treatment group.

Group	White	Black	Hispanic	Asian	Indian	Multi-racial	Total
Control	29	36	15	3	0	2	85
RRCU	47	60	48	3	1	3	162
Total	76	96	63	6	1	5	247

Table 4.3 – Study participants by learning status in control and treatment group.

Group	Student with Disability	Emotionally Disturbed	Limited English Proficiency	Total
Control	12	61	0	73
RRCU	11	119	7	137
Total	23	180	7	210

Additionally a total of six teachers' students were included in the study, control group students were unequally split among two teachers and the experimental group included

students from four teachers, also unequally split. See Table 4.4 for a breakdown of students by teacher and group. The control group was about half as large as the experimental group.

Table 4.4 – Study participants by teacher and group.

Group	Teacher 1	Teacher 2	Teacher 3	Teacher 4	Teacher 5	Teacher 6	Total
Control	80	5	0	0	0	0	85
RRCU	0	0	100	35	14	13	162

Tests for Normality and Descriptive Statistics

Prior to running the analyses, it was necessary to establish the likelihood that the data came from a normal distribution. For all data, the distribution was normal or close to normal and therefore the original data were used without transformation in all statistical analyses. Table 4.5 identifies the skewness values for the District Benchmark tests in Biology dataset which reveal the asymmetry of a distribution, values of 0 indicate the tails of the distribution are equal. Basic descriptive data are also included in the table including the number of subjects, mean, median and mode.

Table 4.5 – Descriptive Statistics and Normality Test Results for Biology Data

	Bio Pre-test	Bio Quarter 1	Bio Quarter 2	Bio Post-test
N	234	246	246	246
Mean	37.405	48.776	52.036	47.340
Median	36.000	46.000	52.000	45.000
Mode	38.000	46.000	58.000	45.000
Std Deviation	14.854	14.717	15.452	17.215
Std error of the mean	0.9710	0.938	0.985	1.095
Skewness	1.0511	0.272	0.066	0.653
Variance	220.654	216.615	238.794	296.387
Kurtosis	1.366	-0.430	-0.649	-0.003
Uncorrected SS	378827	638339	724625	626459
Corrected SS	514112.431	53070.703	58504.670	72911.433
Coefficient Variation	39.711	30.174	29.696	36.366
Range	75.000	74.000	70.000	75.000

For example, for the Biology Quarter 1 test results, the skewness value was 0.2725, representing the likely similarity between the tails of the distribution and the Kurtosis value was -0.4301, indicating the “peakedness” of the distribution. Both values indicate a normal or close to normal distribution visually represented in Figure 4.1. Table 4.5 reveals similar results were found across tests and therefore the original data were used in all additional analyses.

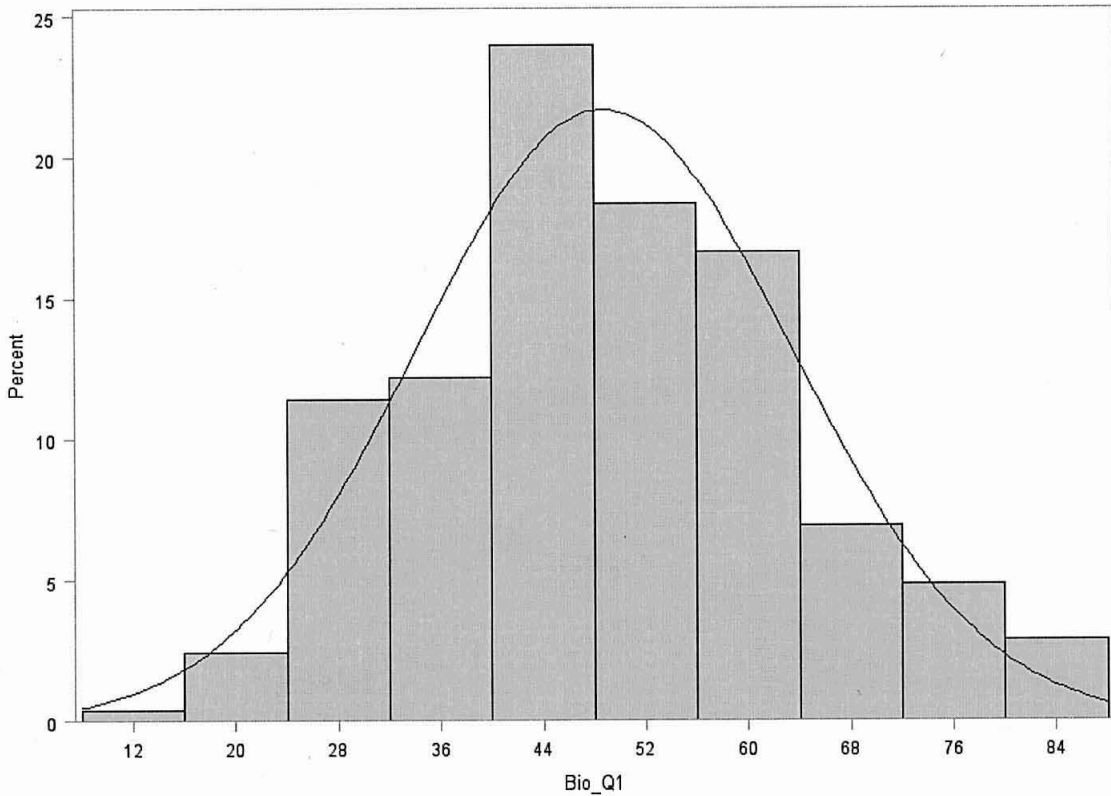


Figure 4.1 – A sample graphical representation of the normality test results to determine the distribution of the District Benchmark Biology Quarter 1 dataset. Results indicate a normal distribution and do not require transformation for further analyses.

Identical tests of normalcy were completed for the District Benchmark Tests in Language Arts and FCAT Reading scores in addition to the generation of descriptive statistics. The results can be found in Appendix D and also indicate a normal distribution, permitting further analyses without transformation.

Results for Research Questions I and II

Research questions one and two were addressed through MANOVA in order to examine the effect of the independent variable, RRCU, on the dependent variables,

student test scores in Biology and Language Arts. MANOVA is preferred over ANOVA because it is likely the dependent variables are correlated, separate ANOVAs would not reveal any correlation among the dependent variables. MANOVA also permits the exploration of the interaction of other variables which may influence the dependent variables such as grade, gender, ethnicity, and learning status (student with disability, limited English proficiency, and emotionally disturbed). A priori testing was conducted to determine which means differ once the MANOVA identified a difference among the means. Duncan's new multiple range test was used because it is especially protective against false negative or Type II error. This does come at the expense of increasing the risk of Type I error or false positives.

The two fundamental questions addressed in this study were: Does RRCU improve student achievement in Biology as measured by District Benchmark tests of Biology and/or does RRCU improve student achievement in Reading as measured by District Benchmark tests of Language Arts? The results of the analysis reveal no significant effect of the RRCU treatment on student tests scores in either Biology or Language Arts. The analysis did reveal a significant effect of grade level on science scores, data for 9th grade Language Arts scores was not available and therefore not analyzed. Although gender did not have an effect on science scores, there was a significant difference between boys and girls in reading as measured both by FCAT Reading and by District Benchmark tests of Language Arts with girls outperforming boys. Significant differences were identified between ethnic groups on FCAT Reading and students with disabilities consistently scored lower than those without across all

measures. See table 4.6 for a complete list of means and identification of significant differences for the main effects of the variables on test scores.

Table 4.6 – Main effects of Group (0 = control, 1 = RRCU), Grade, Gender, Ethnicity, Limited English Proficiency, Student with Disability, and Emotionally Disturbed on all measures including FCAT Reading, District Benchmark Biology tests and Language Arts test.									
Variable	Reading (Mean)	Bio_Prestest (Mean)	Bio_Q1 (Mean)	Bio_Q2 (Mean)	Bio_Q3 (Mean)	LA_Prestest (Mean)	LA_Q1 (Mean)	LA_Q2 (Mean)	LA_Q3 (Mean)
Group									
0	308.9 ^A	36.4 ^A	48.3 ^A	52.6 ^A	48.9 ^A	60.0 ^A	55.2 ^A	61.9 ^A	57.7 ^A
1	305.1 ^A	38.0 ^A	49.0 ^A	51.8 ^A	46.5 ^A	57.4 ^A	55.3 ^A	59.5 ^A	57.4 ^A
	NS	NS	NS	NS	NS	NS	NS	NS	NS
Grade									
9	353.6 ^A	74.6 ^A	72.3 ^A	70.4 ^A	83.6 ^A	NA	NA	NA	NA
10	303.6 ^B	35.0 ^B	47.4 ^B	50.9 ^B	45.2 ^B	58.4	55.3	60.4	57.5
	****	****	****	****	****				
Gen									
F	311.1 ^A	36.4 ^A	48.7 ^A	52.7 ^A	47.2 ^A	60.2 ^A	58.0 ^A	62.4 ^A	59.4 ^A
M	298.8 ^B	39.2 ^A	49.0 ^A	50.9 ^A	47.5 ^A	55.1 ^B	50.1 ^B	56.8 ^B	53.9 ^B
	**	NS	NS	NS	NS	**	****	**	**
ETH									
A	309.7 ^B	40.3 ^A	48.5 ^A	56.5 ^A	48.0 ^A	61.0 ^A	46.2 ^A	62.6 ^A	57.4 ^A
B	292.4 ^B	32.4 ^A	45.5 ^A	49.1 ^A	43.4 ^A	56.3 ^A	54.3 ^A	57.7 ^A	56.1 ^A
H	304.1 ^B	35.0 ^A	48.2 ^A	49.2 ^A	45.5 ^A	55.6 ^A	54.3 ^A	61.4 ^A	57.3 ^A
I	369.0 ^A	36.0 ^A	54.0 ^A	64.0 ^A	55.0 ^A	84.0 ^A	66.0 ^A	73.0 ^A	73.0 ^A
M	302.8 ^B	36.2 ^A	47.0 ^A	53.6 ^A	46.2 ^A	58.6 ^A	58.8 ^A	60.6 ^A	61.4 ^A
W	325.2 ^{AB}	46.0 ^A	53.6 ^A	57.5 ^A	53.8 ^A	63.9 ^A	58.2 ^A	63.4 ^A	59.6 ^A
	***	NS	NS	NS	NS	NS	NS	NS	NS
LEP									
N	308.3 ^A	37.6 ^A	49.2 ^A	52.2 ^A	47.6 ^A	58.9 ^A	55.5 ^A	60.6 ^A	57.8 ^A
Y	242.4 ^B	28.0 ^A	35.1 ^B	47.4 ^A	38.7 ^A	35.8 ^B	46.2 ^A	51.4 ^A	45.4 ^A
	***	NS	*	NS	NS	**	NS	NS	NS
SWD									
N	310.6 ^A	38.4 ^A	49.9 ^A	53.6 ^A	48.4 ^A	60.1 ^A	56.9 ^A	62.1 ^A	59.1 ^A
Y	265.6 ^B	27.9 ^B	37.5 ^B	37.1 ^B	37.2 ^B	43.6 ^B	42.0 ^B	45.9 ^B	44.4 ^B
	****	**	***	****	**	****	****	****	****
ED									
N	318.3 ^A	43.4 ^A	52.9 ^A	57.4 ^A	53.9 ^A	63.4 ^A	57.0 ^A	61.8 ^A	60.6 ^A
Y	302.0 ^A	35.2 ^A	47.3 ^A	50.1 ^B	44.9 ^A	56.8 ^B	54.8 ^A	60.0 ^A	56.6 ^A
	NS	NS	NS	*	NS	*	NS	NS	NS

† Means with the same letter for each variable are not significantly different at $\alpha=0.05$.

****Significant at $P<0.0001$, ***Significant at $P<0.001$, **Significant at $P<0.01$, *Significant at $P<0.05$, NS=not significant, NA=not available.

The interaction of group with the other variables had no effect on District Benchmark Tests of Biology scores. However, there were some interactions of group with the gender, emotionally disturbed, and ethnicity variables on FCAT Reading and Language Arts. These may be a result of an increase in Type I error due to the use of Duncan's new multiple range test since both FCAT Reading and the Language Arts Pre-test were administered prior to the treatment. See table 4.7 for a complete listing of interactions with a significant effect.

Table 4.7 – Interactions of Group (Control and RRCU) with gender, emotionally disturbed, and ethnicity on the results of FCAT Reading, and District Benchmark tests of Language Arts.

Variable	Reading (Mean)	La_Pretest (Mean)	La_Q1 (Mean)	La_Q2 (Mean)	La_Q3 (Mean)
Group 0					
Gen F	320.4 ^A	64.0 ^A	58.8 ^A	64.7 ^A	60.0 ^A
Gen M	293.9 ^B	54.9 ^B	50.6 ^B	58.3 ^{BC}	54.8 ^{AB}
Group 1					
Gen F	306.9 ^{AB}	58.3 ^{AB}	57.6 ^A	61.2 ^{AB}	59.1 ^A
Gen M	301.9 ^B	55.3 ^B	49.7 ^B	55.3 ^C	53.2 ^B
	*	*	**	*	*
Group 0					
ED N	316.8 ^{AB}	62.2 ^{AB}	.	.	.
ED Y	305.8 ^{AB}	59.2 ^{AB}	.	.	.
Group 1					
ED N	319.2 ^A	64.4 ^A	.	.	.
ED Y	300.0 ^B	55.5 ^B	.	.	.
	*	*	NS	NS	NS
Group 0					
ETH					
A	307.7 ^{AB}	67.0 ^{AB}	.	.	.
B	286.2 ^B	53.9 ^B	.	.	.
H	312.2 ^{AB}	57.3 ^B	.	.	.
I	NA	NA	.	.	.
M	327.5 ^{AB}	67.0 ^{AB}	.	.	.
W	334.2 ^{AB}	67.9 ^{AB}	.	.	.
Group 1					
ETH					
A	311.7 ^{AB}	52.0 ^B	.	.	.
B	296.1 ^B	57.8 ^B	.	.	.
H	301.5 ^B	55.0 ^B	.	.	.
I	369.0 ^A	84.0 ^A	.	.	.
M	286.3 ^B	53.0 ^B	.	.	.
W	319.7 ^{AB}	59.8 ^{AB}	.	.	.
	***	*	NS	NS	NS

† Means with the same letter for each variable are not significantly different at $\alpha=0.05$.

****Significant at $P<0.0001$, ***Significant at $P<0.001$, **Significant at $P<0.01$, *Significant at $P<0.05$, NS=not significant, NA=not available.

The key finding is Read, Retrieve, Connect and Use had no significant effect on student scores in either Biology or Language Arts as implemented in this study.

To complete the analysis a Stepwise and Backward Linear Regression test was used to discover if FCAT Reading or District Benchmark tests in Language Arts have an impact on District Benchmark tests in Biology. This test begins with all variables and subsequently deletes the variable that improves the model the most (the variable with the weakest impact on the dependent variable). This process is repeated until no further improvement is possible. The results provide coefficients for each independent variable, and the degree each independent variable combined with the others, predicts the dependent variable. In turn, a mathematical model for predicting students' scores on District Benchmark tests in Biology using FCAT Reading scores and/or District Benchmark tests in Language Arts is created. Although District Benchmark tests in Language Arts, particularly the post-test (Quarter 3) appear to predict Biology scores, FCAT reading level was a robust and consistent predictor of Biology scores as evident in Tables 4.9 – 4.12.

Table 4.9 - Summary of Stepwise Selection for District Benchmark in Biology Pre-test. Only variables with a significant impact on student scores are identified.

Step	Variable Entered	Variable Removed	Number Vars In	Partial R-Square	Model R-Square	C(p)	F Value	Pr > F
1	Reading		1	0.2864	0.2864	23.3119	87.51	<.0001
2	LA_Pretest		2	0.0509	0.3373	8.2490	16.66	<.0001
3	LA_Q1		3	0.0130	0.3503	5.8851	4.33	0.0387

Table 4.10 - Summary of Stepwise Selection for District Benchmark in Biology Quarter 1 test. Only variables with a significant impact on student scores are identified.

Step	Variable Entered	Variable Removed	Number Vars In	Partial R-Square	Model R-Square	C(p)	F Value	Pr > F
1	Reading		1	0.4126	0.4126	16.8173	152.41	<.0001
2	LA_Q2		2	0.0283	0.4409	7.6431	10.94	0.0011
3	LA_Q3		3	0.0117	0.4526	5.0335	4.59	0.0333

Table 4.11 - Summary of Stepwise Selection for District Benchmark in Biology Quarter 2 test. Only variables with a significant impact on student scores are identified.

Step	Variable Entered	Variable Removed	Number Vars In	Partial R-Square	Model R-Square	C(p)	F Value	Pr > F
1	Reading		1	0.4265	0.4265	36.6746	161.36	<.0001
2	LA_Q3		2	0.0588	0.4853	12.8641	24.68	<.0001
3	LA_Q1		3	0.0217	0.5070	5.3441	9.46	0.0024
4	LA_Pretest		4	0.0074	0.5144	4.0932	3.26	0.0722

Table 4.12 - Summary of Stepwise Selection for District Benchmark in Biology Quarter 3 test (post-test). Only variables with a significant impact on student scores are identified.

Step	Variable Entered	Variable Removed	Number Vars In	Partial R-Square	Model R-Square	C(p)	F Value	Pr > F
1	Reading		1	0.3874	0.3874	35.6713	137.84	<.0001
2	LA_Q3		2	0.0561	0.4435	14.6054	21.89	<.0001
3	LA_Q1		3	0.0317	0.4752	3.5982	13.03	0.0004

The key finding from this set of analyses is that student reading level as measured by FCAT Reading is highly correlated, and likely predictive, of student achievement on District Benchmark Biology assessments.

Results for Research Question Four

The final component of this study was designed to explore how teachers used RRCU in their classrooms. A semi-structured survey was emailed to teachers identified by their site supervisor as using RRCU. Four teachers were identified as using RRCU as part of their instruction but one teacher did not return the survey. Teachers not using RRCU were not interviewed and therefore no information regarding their classroom instruction is available. The interview was primarily designed to gather information about how teachers used RRCU, whether they felt the strategy was useful and beneficial, how RRCU could be improved, and teacher attitudes towards the strategy. However, the surveys also revealed that teachers had a wide range of implementation styles and that use of RRCU was highly variable, with Teacher 3 using all twelve modules, Teacher 2 using 7-8 modules and Teacher 1 using just three modules.

Teachers used RRCU in various ways. Some teachers implemented the strategy as a bell-ringer activity while others embedded RRCU in instruction as a formative assessment in preparation for summative assessment. All the teachers that responded agreed the strategy was useful for reviewing or reinforcing specific content knowledge. There was also a consensus that RRCU provided an opportunity to build literacy skills through exposure to vocabulary and the use of specific literacy strategies such as summarization.

Surveyed teachers provided little feedback on how the instructional strategy could be improved. Teacher 2's recommendations were more specific to the mechanism of implementation than to the strategy itself. Her improvements addressed the introduction and rationale of the strategy, as she felt a more explicit explanation of the strategy might improve student motivation and learning. Teacher 3 suggested the RRCU strategy might be too challenging for some low-level and/or ESE students. But Teacher 3, also adapted the strategy to meet the needs of those students by permitting students to use highlighters to identify key terms and ideas.

Overall, the participating teachers appeared to have a generally positive attitude towards the Read, Retrieve, Connect and Use modules as two out of three indicated they were interested in attending a workshop to learn more about the strategy and how to implement the modules in their classrooms. Two out of three also ranked RRCU as a 5, on a scale of 1 – 5, with 5 being the best for improving science content knowledge and building literacy skills. Teacher 1 gave RRCU a 3.5, a still positive review although this teacher only used the three of the twelve modules. A summary of the survey questions and teacher responses can be found in Table 4.13.

Table 4.13 – Summary of teacher survey responses regarding their use of the Read, Retrieve, Connect and Use instructional strategy.

Question	Teacher Responses
Describe how you implemented RRCU in your classroom.	T1: Used as a class activity approximately 3 times. Students worked independently. Did not use as an assessment.
	T2: I implemented these for bellringers and during instruction for the purpose of applying learning and increasing relevance, as well as improving scientific literacy. I used maybe 7 or 8 of the modules.
	T3: I implemented the RRCUs with each unit of study,

	<p>depending on where we were in the lessons and how well or not so well my students understood the material. During the beginning of the year, I used them as a review prior to assessment and in doing so I needed to walk the students through them slowly. I realized early on that my class was not able to ascertain what was being asked from the excerpts due to their low level of understanding of the passage. I had to alter the format by reading it to them as a class, stopping and starting when pertinent information arose, having the students actively listen with highlighters in hand. This routine never ceased through the remainder of the year. As a matter of fact, the students grew accustomed to asking for the duty of passing out the highlighters and having a choice of colors to use. Students always worked independently. The only few students who I would see work together were my ESOL students. I did consider it a formative assessment and the students were graded accordingly.</p>
<p>Do you feel RRCU was beneficial for your students in terms of improving content knowledge in science and/or building literacy skills? Why or why not?</p>	<p>T1: I feel it was good for their literacy skills and was a good reinforcement of their previous science knowledge.</p> <p>T2: Yes, I feel it was useful for both. I think the more I used them, the more they would be accustomed to read for understanding. I think it helped increase content knowledge basically in ways that apply learning to real world situations. It was good to have a circumstance too when it could be applied and understood to a greater level or they would learn something more interesting, as in the science of conditioned fear and how that worked in a competitive sense with animals, and as a result of the predator-prey relationship, for example, the number trees would increase or decrease accordingly. How I think this example worked well for increasing their knowledge was to explore the situation in detail instead of giving a tidbit of information as texts might have done when providing examples.</p> <p>T3: I do feel the students benefited from the RRCU. They exposed them to relevant research in the content area, increased their vocabulary, built context clue usage in deciphering the content and the meanings of techniques or mechanisms and forced them to think outside the box. In all honesty, the students did not like the questions because of the manner they pushed their intellect. I received much resistance on the back side of the paper.</p>

How would you improve RRCU?	T1: No response.
	T2: I would introduce this format along with the importance of developing scientific literacy, informing students that this type of format will be employed regularly to improve their skills. I would introduce along with this the literacy standards set-forth by the state, introducing each of the standards, and topically introducing their anchors (or this might be the other way around:)), and in doing so, inform them that each of the standards and two of the anchors will be a focus within the answering of the questions to improve that skill, along with developing the knowledge that will accompany the literacy.
	T3: Content specific literacy is a weak area and any strategy to enhance the learning for our students is beneficial for them and the teachers who promote them. This strategy might need tweaking to meet the needs of ESE students – maybe lower lexile passages.
Would you be interested in attending a workshop on RRCU to learn about the research behind the strategy and ideas for implementation?	T1: No.
	T2: Definitely.
	T3: Yes.
On a scale of 1-5, with 1 being poor and 5 being excellent, how would you rate RRCU as a strategy of improving science content knowledge and building literacy skills?	T1: 3.5
	T2: 5
	T3: 5

The key findings for research question four in this study were one: teachers were highly variable in how they implemented the RRCU instructional strategies, with some teachers implementing just a few of the modules and not the entire program, and two: teachers generally viewed the instructional strategy favorably as an effective means for improving content knowledge and building literacy skills.

Summary of Key Findings

This study addressed four main questions pertaining to the efficacy of the Read, Retrieve, Connect and Use instructional strategy to improve student achievement in biology and reading. The key findings for each research question were:

1. Does the Read, Retrieve, Connect and Use intervention improve academic achievement in life science at the secondary level?

Findings:

There was no significant effect of the Read, Retrieve, Connect and Use instructional strategy on science learning as measured by District Benchmark Biology tests.

2. Does the Read, Retrieve, Connect and Use intervention improve academic achievement in reading at the secondary level?

Findings:

There was no significant effect of the Read, Retrieve, Connect and Use instructional strategy on reading skill as measured by District Benchmark Language Arts tests.

3. Does reading level predict achievement on district benchmark test scores of secondary students in life science courses?

Findings:

Student reading level, as measured by FCAT Reading scores, is highly correlated and likely predictive of student scores on District Benchmark Biology tests.

4. How do teachers implement Read, Retrieve, Connect and Use in the classroom?

Findings:

Implementation of RRCU is highly variable across teachers and sometimes suffers from a lack of fidelity to the recommended guidelines for use in the classroom.

Overall, teachers have a positive attitude towards the strategy and believe it is an effective tool to improve science content knowledge and build student literacy skills.

The following chapter will explore these findings in light of previous research and within the context of the study.

CHAPTER 5: DISCUSSION

This chapter briefly reviews the methodology and major findings, draws conclusions, and makes recommendations based on those conclusions in the context of the current literature.

Brief Review of Methodology and Findings

This study aimed to explore the efficacy of the Read, Retrieve, Connect and Use (RRCU) instructional strategy on improving high school student science content knowledge and literacy skills as measured by District Benchmark tests in Biology and Language Arts. Participants included 247 students across six classrooms during the 2011-2012 academic year. Students and teachers were assigned to groups, control or experimental, based on identification of site supervisors of those teachers already using the RRCU modules as part of their instruction.

The RRCU instructional strategy consists of twelve modules, each module addresses a Next Generation Sunshine State Science Standard (NGSSSS) and a Common Core Standard for Literacy in Science. The modules were designed to help students learn required content knowledge and build literacy skills to prepare them for standardized testing in both science and reading. Each module embeds the retrieval-practice study technique (Karpicke and Blunt, 2011; Karpicke, 2009; Karpicke and Roedinger, 2007) to promote retention of science content and incorporates effective literacy strategies recommended by the National Reading Panel (2000) to promote and build effective reading strategies.

There were four main research questions:

- I. Does the Read, Retrieve, Connect and Use intervention improve academic achievement in life science at the secondary level?
- II. Does the Read, Retrieve, Connect and Use intervention improve academic achievement in reading at the secondary level?
- III. Does reading level predict achievement on district benchmark test scores of secondary students in life science courses?
- IV. How do teachers implement Read, Retrieve, Connect and Use in the classroom?

Questions one and two were addressed through Multiple Analysis of Variance (MANOVA) to identify whether the treatment (RRCU) or an interaction of variables such as gender and ethnicity, impacted the dependent variables, student scores on biology and reading tests. A priori testing, Duncan's new multiple range test, was used to identify which means were significantly difference among the variables tested. The results revealed no significant effect of the RRCU treatment on student test scores in reading or science.

Question three was addressed through a Pearson's correlation analysis and a Stepwise and Backward Regression analysis to identify correlations among the dependent variables and which variables have the most impact and/or are predictive of District Benchmark Biology tests. The analyses revealed student reading level, as measured by FCAT Reading, is highly correlated to and likely predictive of, District Benchmark Biology test

scores. In other words, students with low scores on FCAT Reading, indicating poor reading skill are likely to score poorly on District Benchmark tests in Biology.

Question four was addressed through a survey designed to elicit information on how teachers implemented the RRCU strategy and their attitudes towards RRCU. The survey was brief, just 5 questions (see Table 4.13) and revealed there was great variation in how teachers used RRCU as an instructional tool but that overall teachers held a positive view of the strategy as an effective means to improve student content knowledge and build literacy skills.

Discussion

The Impact of Reading on Student Test Scores in Science

Research suggests that tests of content-knowledge, such as standardized or benchmark science tests, may be assessing reading ability more than content knowledge (Visone, 2009). This potential discrepancy in what is being measured has become particularly poignant in light of the value being placed upon student test scores under No Child Left Behind (NCLB) and Race to the Top (RttT). Many schools and districts have implemented or will implement teacher evaluation plans that use student test scores to determine teacher effectiveness and value to comply with NCLB and RttT.

As a result, teachers require effective instructional tools to ensure students learn and possess the requisite skills necessary to achieve on high-stakes tests. While content area teachers may have focused on content only, research by Visone (2009 and 2010) and O'Reilly and McNamara (2007) clearly indicate student success on standardized science

tests is strongly related to student reading ability. The results of this study add to this body of literature because student reading level, as measured by FCAT Reading scores, was highly predictive and correlated with student scores on District Benchmark Biology tests. These results indicate poor reading skill is a significant obstacle in achieving a high score on science tests.

Poor reading skill may directly affect student test scores in science if students are unable to comprehend what is being asked (Meloy, Deville, and Frisbie, 2000) or if they struggle to identify the main points of informational text passages found on science tests. Poor reading skill may indirectly affect student test scores by reducing the effectiveness of assignments connected to course textbooks since science textbook typically are challenging to read with much technical vocabulary and complex content (van den Broek, 2010; Kamil, 2003). In turn, this impedes the acquisition and retention of content knowledge (Casteel and Isom, 1994).

Students in this study exhibited similar traits to previous studies. Not only was reading skill level tied to science achievement, but there were differences among groups. White students outperformed other groups on both FCAT Reading and on District Level Biology tests. These findings align with the results of both state tests and the National Assessment of Educational Progress according to the Center on Education Policy (2010) which found wide and persistent gaps on reading tests. Similarly, the Florida Department of Education (2011) reports that White students outperformed both African American and Hispanic students on the Science FCAT. Therefore it is likely, that the sample population of this study was representative of Florida students in general with similar characteristics.

Improving student reading skills is a daunting task as numerous studies of various reading interventions have shown little effect. The U.S. Department of Education (2009) reports that the majority of students entering high school are not able to read at grade level. Studies of Project CRISS, ReadAbout, Read for Real, and Reading for Knowledge (all reading intervention programs designed to improve student reading skill) did not reveal any significant effect of the interventions (James-Burdumy et. al., 2009) on reading comprehension. In some cases, intervention groups scored lower than control groups. The results of this study were reflective of these previous results. Improving reading comprehension at the secondary level is a challenging and difficult task.

Based on the results of this study and previous research in the field, student reading skill level directly influences student learning and testing. Moreover, high-stakes content area tests, such as District Benchmark Biology tests and FCAT science tests, may assess student reading ability more than content knowledge. This is particularly concerning given the emphasis of these tests on teacher evaluations and retention and student progression and graduation.

Read, Retrieve, Connect and Use as an Intervention Strategy

Two identified barriers to student success on standardized science exams are lack of content knowledge and poor literacy skills (Visone 2009 and 2010; O'Reilly and McNamara, 2007; RAND, 2002). The RRCU instructional strategy was designed to address both barriers.

A lack of content knowledge is addressed in the RRCU strategy in several ways. First, each module addresses a core content standard clearly identified on the module.

Second, authentic and relevant articles connected to the standard are used. Third, the retrieval-practice study technique (Karpicke and Blunt, 2011) is embedded in the model to increase retention of content knowledge. And fourth, questions designed to access domain knowledge and prior experience permit students to make connections between and across content knowledge.

RRCU was also designed to improve literacy skills by providing students numerous opportunities to interact with informational text and to use evidenced-based strategies to improve reading comprehension identified by the National Reading Panel (2000). These strategies include exposure to technical vocabulary, comprehension monitoring, question answering and summarization. Research by Sweet (2000) indicated that effective reading instruction developed engaged and motivated readers who demonstrated greater proficiency in both reading and content areas. Numerous researchers (Ulusoy and Dedeoglu, 2011; Ness, 2009) argue secondary content area teachers must employ explicit reading instruction.

Yet, little explicit reading instruction is taking place in secondary content area classroom (Ness, 2008). In fact, subject-specific teachers (particularly science teachers) tend to be reticent and reluctant to incorporate literacy skills into their instruction (Ulusoy and Dedeoglu, 2011; Ness, 2009). However, these same teachers acknowledge that many of their students had serious reading and comprehension problems. This should not be surprising given the FCAT Reading scores and District Benchmark Language Arts scores in this study, the majority of students were not scoring on grade level or passing. These findings mirror the results across the state and the nation.

The Common Core Standards for Literacy in Science were also addressed in the RRCU instructional strategy. The Common Core Standards have been adopted by 48 states and outline a framework for scientific literacy. This framework focuses on applying literacy skills to scientific, technical, and informational texts to prepare students for college and careers. Each RRCU module focused on a single Common Core Standard for Literacy in Science, such as, “Determine the central ideas or conclusions of a text.” The standard is clearly identified at the beginning of the module for both teacher and student and at least one question specifically addressed the standard. The RRCU strategy addressed content knowledge, by having students work with pertinent text connected to a required content standard, and literacy, through the use of the Common Core Standards for Literacy in Science.

While RRCU was well-received by teachers, the results of this study did not confirm that RRCU was an effective strategy for improving either science content knowledge or literacy skills as measured by District Benchmark tests in Biology and Language Arts. However, there are some significant flaws in the study’s design that may question the validity of the results.

Although the number of student participants was over 200, there were just six teachers involved. Four of them used RRCU, but there was great variability in use and implementation. At least half of the participating teachers did not fully implement all twelve modules. The control group overwhelming consisted of a single teacher and their students, who may or may not be representative of teachers in general. For example, the

control group may have consisted of highly experienced and effective teachers and the experimental group may have consisted of less experienced and new teachers.

Nearly 20% of students eligible for the study (enrolled in a biology course at a participating school) were missing data and had to be excluded from the study. This number was even higher (33%) for the control group. It is impossible to know the effect these students might have had on the group mean had they been tested and included.

Based on the results of this study, it is not possible to conclude that Read, Retrieve, Connect and Use is an effective strategy to improve science content knowledge and literacy skills. Neither is it possible to objectively determine it is not effective given the limitations in the design and implementation of the study.

Teacher Attitudes Towards Read, Retrieve, Connect and Use

Teachers who used RRCU reported a positive attitude towards the instructional strategy indicating they felt it was effective in promoting content knowledge and literacy skills. According to Kamil (2003), Ness (2008) Ulusoy and Dedeoglu (2011) content area teachers do not spend a significant portion, if any, of class time on explicit reading instruction. This may be due to the increased testing requirements in science content, pushing literacy instruction into the background. Science teacher may also assume that the teaching of reading is not their responsibility or within their field of expertise (Ulusoy and Dedeoglu, 2011). Clearly, it is a challenging task to motivate science teachers to include explicit literacy instruction.

Most states are currently in the process of aligning curriculum to the new Common Core Standards, including those for Science Literacy. The new standards will place an additional burden on science teachers as they strive to create lesson plans and curriculum in accordance with the requirements of the Common Core standards while continuing to meet the requirements of their state standards in science. RRCU already combines state science standards and the Common Core Standards for Literacy in Science with evidence-based strategies for improving reading comprehension.

It is evident that specific and explicit reading strategies must be incorporated into science classrooms to improve student learning and achievement. It is also evident that secondary teachers, particularly science teachers, do not include specific literacy pedagogy as part of their regular instruction despite the acknowledged need for such instruction. Read, Retrieve, Connect and Use may serve as a palatable mechanism to encourage and support secondary science teachers in promoting explicit reading instruction without reducing time spent on required content.

Based on the results of this study, RRCU was viewed by teachers as a useful and effective strategy for improving student content knowledge in Biology and improving literacy skills. Teachers clearly indicated the need for both content and reading instruction among their students.

Limitations

There are several limitations of this study. The non-random nature of sampling is problematic in several ways. One, teachers that opt to use RRCU as part of their teaching may share characteristics that impact student test scores separate from the RRCU

strategy. Two, students may not be randomly assigned to biology sections but instead may also share similar characteristics that could impact test scores. For example, students who do not score on grade level for reading must take an intensive reading course, enrollment in that course could influence what section (and therefore teacher) a student is assigned for biology. Three, there was an unequal spread of teachers and students in the treatment and control groups. The control group was half the size of the treatment group and was overly represented with a single teacher's students. This one teacher therefore had a large effect on the control group mean.

The overall sample size was not as large as desired. The sample population came from only two of five traditional high schools in the district and included about 250 students. A good portion of student data had to be eliminated from the analyses due to missing data points. The elimination of these students and their scores could have skewed the results in either direction.

Teachers using the RRCU strategy did not participate in any kind of training related to the use of RRCU. As a result, there was great variability in how teachers fit RRCU into their instruction and how often. At least half of the participating teachers did not complete all twelve modules, making it difficult to assess the effect of RRCU on student achievement.

With pressure from state and federal governments to improve student achievement, districts and school are implementing numerous intervention and reform strategies. It is difficult to isolate the effect of one strategy from another and often to even identify which strategies are being implemented and how by individual teachers.

Additionally, interventions and reforms may interact to impact student achievement and not necessarily in a positive way.

Conclusions

Although the study results did not indicate RRCU was an effective means of increasing student achievement, it is important to note that aspects of the study design may have limited the accuracy and validity of these results. Previous research on literacy intervention strategies suggests it is a challenging obstacle to overcome poor reading skills, particularly among secondary students. However, it is also evident that science and scientific literacy are key components for the continued success and progress of our nation. Therefore, it is imperative the educators continue to seek means to improve basic literacy skills to facilitate the development of science and scientific literacy among our nation's students.

Given the literature and the results of this study, student reading skill level has a significant impact on student achievement on standardized tests in content areas such as science. Yet, few secondary content area teachers include explicit literacy instruction in their classroom despite acknowledging many students struggle with reading. Read, Retrieve, Connect and Use was positively received by teachers as an effective tool to improve science content knowledge and literacy skills. Additionally, RRCU provides an easy mechanism for teachers to align their curriculum with state science standards, the Common Core Standards for Literacy in Science and evidence-based reading strategies. As such, RRCU offers teachers an easy opportunity to enact explicit reading instruction

without time off content, while also permitting schools and states to comply with the new Common Core Standards.

Recommendations for Future Research

The limitations of this study should be addressed in future research. To improve upon the design of this study would require:

- Random assignment to control/experimental group.
- Increase the number of participating teachers.
- Match teachers in control and experimental groups based on years of experience or other credentials.
- Balance the number of teachers and students in each group.
- Encourage school sites to improve testing and data collection for all students.
- Provide training on the science of the RRCU strategy and appropriate implementation in the classroom to all participating teachers.
- Expand the scope of the survey to collect information from all participating teachers (control and experimental) to gather more data on how RRCU was used and on teacher characteristics that may influence student achievement.
- Increase the number of participating schools.

This study was hampered by the uneven distribution of teachers and students assigned to the control and experimental group as well as the lack of fidelity in the use of the RRCU modules. These two main issues could easily be addressed in a future study. Collecting more and better data from teachers could reveal specific teacher and/or instructional

characteristics that impact student achievement. Such findings may be useful in modifying current instructional strategies for all teachers to improve student science content knowledge and literacy.

Implications for Practice

The results of this study and previous research affirm the difficulty of improving student science content knowledge and literacy skills at the secondary level. Given the need to improve student achievement in both reading and science, there is a necessity to identify effective means to improve both.

Improving student science content knowledge likely rests on student reading ability. While intervention strategies at the high school level may be necessary, those interventions are likely needed earlier on in a student's educational career. The Read, Retrieve, Connect and Use modules could be expanded and modified for use at the middle school level. Given the depth and complexity of science content and concepts in high school, building a foundation of strong literacy skills during middle school could help students attack more complex text as they progress.

The district involved in this study, like many districts, has struggled to dramatically improve student achievement in science despite numerous and well-intentioned reforms and interventions. Given the positive teacher feedback on RRCU, it may serve the district well to continue encouraging teachers to employ the strategy and monitor the use of RRCU as a potential mechanism for improving science and scientific literacy in the district.

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APPENDIX A

Read, Retrieve, Connect and Use Modules

NAME: _____ DATE: _____ PER: _____

BIOLOGY

Scientific Process**READ RETRIEVE CONNECT & USE****Next Generation Sunshine State Standard**

SC.912.N.1.1: Define a problem based on a specific body of knowledge, for example: biology and do the following: plan investigations and communicate results of scientific investigations.

Common Core Scientific Literacy Standard

Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.

Aquarium Fishes Are More Aggressive in Reduced Environments, New Study Finds

ScienceDaily (Sep. 21, 2011) — An angry glare from the family goldfish might not be the result of a missed meal, but a too-humble abode. Fish in a cramped, barren space turn mean, a study from Case Western Reserve University has found. Ornamental fishes across the U.S. might be at risk, all 182.9 million of them. "The welfare of aquarium fishes may not seem important, but with that many of them in captivity, they become a big deal," said Ronald Oldfield, an instructor of biology at Case Western Reserve. Why, then, has the welfare of pet fishes been overlooked among the scientific community?

Oldfield is the first to scientifically study how the environment of home aquariums affects the aggressive behavior of ornamental fishes. Oldfield compared the behavior of Midas cichlids (*Amphilophus citrinellus*) in a variety of environments: within their native range in a crater lake in Nicaragua, in a large artificial stream in a zoo, and in small tanks of the sizes typically used to by pet owners

Along with environment size, Oldfield tested the complexity of an environment and the effects of number of fish within tanks. The addition of obstacles and hiding places using rocks, plants, or other similar objects can increase the complexity of the aquarium environment. He found that an increase in tank size and complexity can reduce harmful aggressive behaviors, and make for healthier fish at home.

Oldfield quantified aggressive behavior as a series of displays and attacks separated by at least a second. Displays are body signals such as flaring fins. An attack could be a nip, chase, or charge at another fish. In aquariums, these behaviors can lead to injury and in extreme cases to death.

Aggressive behavior was not correlated with small-scale changes in either group size or habitat size alone. However, a significant difference was observed in environments sufficiently large and complex: fish spent less time exhibiting aggressive behavior.

"This more natural environment elicits more natural behaviors, which are more interesting to observers," Oldfield said. And, for the fish themselves, their lives can be vastly improved with these simple changes to their environments. "If we are going to try to create a society as just as possible, we need to do everything we can to minimize negative effects," Oldfield said.

Case Western Reserve University (2011, September 22). Aquarium fishes are more aggressive in reduced environments, new study finds. *ScienceDaily*. Retrieved September 26, 2011, from <http://www.sciencedaily.com/releases/2011/09/110922102241.htm>

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NAME: _____ DATE: _____ PER: _____

BIOLOGY

1. Read the article, "Aquarium fishes are more aggressive in reduced environments." After reading the article (5-10 minutes), write down everything you can remember in the box below. The process of recalling the information is important, so do not return to the article at this point.

2. Return to the article if necessary and answer the following questions. You may also need to draw from your knowledge of biology and you should feel free to use your text or other resource.

a) Identify the independent variable of this study (the manipulated variable)?

b) Identify the dependent variable of this study (the measured or responding variable)?

c) Using your independent and dependent variable, form a hypothesis for this study.

d) Describe some examples of aggressive behavior on the part of the fish subjects.

e) What is the main conclusion of the author regarding aquarium habitats for pet fish?

NAME: _____ DATE: _____ PER: _____

Cell Membrane Proteins**READ RETRIEVE CONNECT & USE****Next Generation Sunshine State Standard**

SC.912.L.14.2: Compare and contrast the general structures of plants and animal cells. Explain the role of cell membranes as a highly selective barrier (passive and active transport).

Common Core Scientific Literacy Standard

Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.

Chemists Concoct New Agents to Easily Study Critical Cell Proteins

ScienceDaily (Oct. 31, 2010) — They are the portals to the cell, gateways through which critical signals and chemicals are exchanged between living cells and their environments.

But these gateways -- proteins that span the cell membrane and connect the world outside the cell to its vital inner workings -- remain, for the most part, black boxes with little known about their structures and how they work. They are of intense interest to scientists as they are the targets on which many drugs act, but are notoriously difficult to study because extracting these proteins intact from cell membranes is tricky.

Now, however, a team of scientists from the University of Wisconsin-Madison and Stanford University has devised a technology to more easily obtain membrane proteins for study. Writing the week of Oct. 31 in the journal *Nature Methods*, the group reports the development of a class of agents capable of extracting complex membrane proteins without distorting their shape, a key to understanding how they work.

"The proteins are embedded in the membrane to control what gets into the cell and what gets out," explains Samuel Gellman, a UW-Madison professor of chemistry and a senior author of the paper along with Brian Kobilka of Stanford and Bernadette Byrne of Imperial College London. "If we want to understand life at the molecular level, we need to understand the properties and functions of these membrane proteins."

The catch with membrane proteins and unleashing their potential, however, is getting insight into their physical properties, says Gellman.

Like other kinds of proteins, membrane proteins exhibit a complex pattern of folding, and determining the three-dimensional shapes they assume in the membrane provides essential insight into how they do business.

Proteins are workhorse molecules in any organism, and myriad proteins are known. Structures have been solved for many thousands of so-called "soluble" proteins, but only a couple of hundred membrane protein structures are known, Gellman notes. This contrast is important because roughly one-third of the proteins encoded in the human genome appear to be membrane proteins.

To effectively study a protein, scientists must have access to it. A primary obstacle has been simply getting proteins out of the membrane while maintaining their functional shapes. To that end, Gellman's group has developed a family of new chemical agents, known as amphiphiles, that are easily prepared, customizable to specific proteins and cheap.

"These amphiphiles are very simple," says Gellman. "That's one of their charms. The other is that they can be tuned to pull out many different kinds of proteins."

University of Wisconsin-Madison (2010, October 31). Chemists concoct new agents to easily study critical cell proteins. *ScienceDaily*. Retrieved September 22, 2011, from <http://www.sciencedaily.com/releases/2010/10/101031154013.htm>

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NAME: _____ DATE: _____ PER: _____

1. Read the article, "Chemists concoct new agents to easily study critical cell proteins." After reading the article (5-10 minutes), write down everything you can remember in the box below. The process of recalling the information is important, so do not return to the article at this point.

2. Return to the article if necessary and answer the following questions. You may also need to draw from your knowledge of biology and you should feel free to use your text or other resource.

a) What is the primary function of the cell membrane?

b) Explain the role of the proteins discussed in the article in relation to the function of the cell membrane.

c) What happens to the function of a protein if the shape of the protein is changed?

d) Using the article, cite four benefits of amphiphiles.

NAME: _____ DATE: _____ PER: _____

BIOLOGY

Food Webs and Energy**READ RETRIEVE CONNECT & USE****Next Generation Sunshine State Standard**

SC.912.L.17.9: Use a food web to identify and distinguish producers, consumers, and decomposers. Explain the pathway of energy transfer through trophic levels and the reduction of available energy at successive trophic levels.

Common Core Scientific Literacy Standard

Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem.

Are Wolves the Pronghorn's Best Friend?

ScienceDaily (Mar. 3, 2008) — As western states debate removing the gray wolf from protection under the Endangered Species Act, a new study by the Wildlife Conservation Society cautions that doing so may result in an unintended decline in another species: the pronghorn, a uniquely North American animal that resembles an African antelope.

The study, appearing in the latest issue of the journal *Ecology*, says that fewer wolves mean more coyotes, which can prey heavily on pronghorn fawns if the delicate balance between predators and their prey is altered. According to the study, healthy wolf packs keep coyote numbers in check, while rarely feeding on pronghorn fawns themselves. As a result, fawns have higher survival rates when wolves are present in an ecosystem.

"People tend to think that more wolves always mean fewer prey," said WCS researcher Dr. Kim Berger, lead author of the study. "But in this case, wolves are so much bigger than coyotes that it doesn't make sense for them to waste time searching for pronghorn fawns. It would be like trying to feed an entire family on a single Big Mac."

Over a three-year period, researchers radio-collared more than 100 fawns in wolf-free and wolf-abundant areas of Grand Teton National Park and monitored their survival throughout the summer. The results showed that only 10 percent of fawns survived in areas lacking wolves, but where coyote densities were higher. In areas where wolves were abundant, 34 percent of pronghorn fawns survived. Wolves reduce coyote numbers by killing them outright or by causing them to shift to safer areas of the Park not utilized by wolves.

While pronghorn are not endangered, the population that summers in Grand Teton National Park, part of the Greater Yellowstone Ecosystem, had been reduced to fewer than 200 animals in recent years. Since wolves were reintroduced in 1995, the pronghorn population in Grand Teton has increased by approximately 50 percent. These pronghorn have the longest migration -- more than 200 miles roundtrip -- of any land mammal in the lower 48 states. The Wildlife Conservation Society has called for permanent protection of their migration corridor, known as "Path of the Pronghorn," to prevent the animals from going extinct in the Park. Representatives from the National Park Service, U.S. Fish and Wildlife Service, and U.S. Forest Service recently pledged support for protecting the corridor.

If delisting occurs, Wyoming and Idaho have announced their intention to reduce wolf number by 50 percent and 80 percent, respectively. At present, there are an estimated 300 wolves in Wyoming and 700 in Idaho.

"This study shows just how complex relationships between predators and their prey can be," said Berger. "It's an important reminder that we often don't understand ecosystems nearly as well as we think we do, and that our efforts to manipulate them can have unexpected consequences."

Wildlife Conservation Society (2008, March 3). Are Wolves The Pronghorn's Best Friend?. *ScienceDaily*. Retrieved January 21, 2012, from <http://www.sciencedaily.com/releases/2008/03/080303145300.htm>

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NAME: _____ DATE: _____ PER: _____

BIOLOGY

1. Read the article, "Are wolves the pronghorn's best friend?" After reading the article (5-10 minutes), write down everything you can remember in the box below. The process of recalling the information is important, so do not return to the article at this point.

2. Return to the article if necessary and answer the following questions. You may also need to draw from your knowledge of biology and you should feel free to use your text or other resource.

a) Differentiate between consumer and producer. Provide an example of each from the article.

b) How much energy is typically transferred from one trophic level to another? Why?

c) Based on your answer to b, explain why wolves do not tend to prey on pronghorn fawns.

d) What evidence is provided by the author that indicates healthy wolf populations benefit the pronghorns?

NAME: _____ DATE: _____ PER: _____

BIOLOGY

Inheritance Patterns**READ RETRIEVE CONNECT & USE****Next Generation Sunshine State Standard**

SC.912.L.16.2: Discuss observed inheritance patterns caused by various modes of inheritance, including dominant, recessive, codominant, sex-linked, polygenic, and multiple alleles.

Common Core Scientific Literacy Standard

Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts.

No Single Gene For Eye Color, Researchers Prove

ScienceDaily (Feb. 22, 2007) — A study by researchers from The University of Queensland's Institute for Molecular Bioscience (IMB) and the Queensland Institute of Medical Research is the first to prove conclusively that there is no single gene for eye colour.

Instead, it found that several genes determine the colour of an individual's eyes, although some have more influence than others. "Each individual has two versions of a gene, inheriting one from each parent, and these versions can be the same as each other or different," Dr Rick Sturm, the IMB researcher who led the study, said.

"It used to be thought that eye colour was what we call a simple Mendelian recessive trait - in other words, brown eye colour was dominant over blue, so a person with two brown versions of the gene or a brown and a blue would have brown eyes, and only two blues with no brown could produce blue eyes.

"But the model of eye colour inheritance using a single gene is insufficient to explain the range of eye colours that appear in humans. We believe instead that there are two major genes - one that controls for brown or blue, and one that controls for green or hazel - and others that modify this trait.

"So contrary to what used to be thought, it is possible for two blue-eyed parents to have a brown-eyed child, although this is not common."

Dr Sturm likens the system to a light bulb. "The mechanism that determines whether an eye is brown or blue is like switching on a light, whereas an eye becoming green or hazel is more like someone unscrewing the light bulb and putting in a different one."

The study was carried out to clarify the role of the OCA2 gene in the inheritance of eye colour and other pigimentary traits associated with skin cancer risk in white populations, and examined nearly 4000 adolescent twins, their siblings and their parents over five years.

The findings are published in this month's edition of the American Journal of Human Genetics, and were supported with grants from Australia's National Health and Medical Research Council and the United States of America's National Cancer Institute.

University of Queensland (2007, February 22). No Single Gene For Eye Color, Researchers Prove. *ScienceDaily*. Retrieved November 6, 2011, from <http://www.sciencedaily.com/releases/2007/02/070222180729.htm>

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NAME: _____ DATE: _____ PER: _____

BIOLOGY

1. Read the article, "No single gene for eye colour, researchers prove." After reading the article (5-10 minutes), write down everything you can remember in the box below. The process of recalling the information is important, so do not return to the article at this point.

2. Return to the article if necessary and answer the following questions. You may also need to draw from your knowledge of biology and you should feel free to use your text or other resource.

a) What is meant by a dominant/recessive inheritance pattern?

b) What is polygenic inheritance?

c) Based on this article, would you say that eye colour is a dominant/recessive or polygenic pattern of inheritance? Provide support for your claim.

d) How does this article support or not support your previous knowledge about how eye colour is inherited?

NAME: _____ DATE: _____ PER: _____

BIOLOGY

READ RETRIEVE CONNECT & USE**Mitosis****Next Generation Sunshine State Standard**

SC.912.L.16.14: Describe the cell cycle, including the process of mitosis. Explain the role of mitosis in the formation of new cells and its importance in maintaining chromosome number during asexual reproduction.

Common Core Scientific Literacy Standard

Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts.

Mitosis Gets Harder Thanks To New Gene Discovery

ScienceDaily (Apr. 3, 2008) — A biological process taught to every student studying biology has just become a little more complicated thanks to a new discovery. Scientists from the University of Bath have found that a protein called RASSF7 is essential for mitosis, the process by which a cell divides in two.

In research published in the journal *Molecular Biology of the Cell*, the scientists have shown that the protein is essential for building the microtubules that allow the two halves of the cell to slide apart. "What makes mitosis so interesting is that it is one of the biological processes that everyone remembers from their days at school," said Dr Andrew Chalmers from the University's Department of Biology & Biochemistry.

"As well as being one of Nature's most important processes, our interest in mitosis stems from the fact that if you want to kill cancer cells, then stopping them from dividing is a useful way of doing this.

"Several cancer treatments block cell division by targeting microtubules, Taxol is a well known example. It is even possible that RASSF7 might be a future drug target".

During the different phases of mitosis the pairs of chromosomes within the cell condense and attach to microtubule fibres that pull the sister chromatids to opposite sides of the cell. The cell then divides in cytokinesis, to produce two identical daughter cells.

RASSF7 is the latest of a battery of proteins involved in managing the complex process of mitosis. "During mitosis, the chromosomes containing the DNA are pulled apart in two halves by an array of microtubules centred on the centrosomes," said Dr Chalmers.

"Without the RASSF7 protein, the microtubules do not develop properly and cell division is halted. "This is the first functional study of this protein, and we hope to extend our knowledge of how it works in the future."

The work was carried out in Dr Chalmers laboratory by Dr Victoria Sherwood and two final year undergraduate project students from the University, Ria Manbodh and Carol Sheppard. The research was funded by the Medical Research Council.

University of Bath (2008, April 3). Mitosis Gets Harder Thanks To New Gene Discovery. *ScienceDaily*. Retrieved November 6, 2011, from <http://www.sciencedaily.com/releases/2008/04/080403104400.htm>

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NAME: _____ DATE: _____ PER: _____
BIOLOGY

1. Read the article, "Mitosis gets harder thanks to new gene discovery." After reading the article (5-10 minutes), write down everything you can remember in the box below. The process of recalling the information is important, so do not return to the article at this point.

2. Return to the article if necessary and answer the following questions. You may also need to draw from your knowledge of biology and you should feel free to use your text or other resource.

a) What is the primary goal of mitosis?

b) Sequence the major events of mitosis.

c) Describe the specific role of RASSF7 in mitosis using the information in the article.

d) List three mitosis related concepts from this article that you have also come across in your text, lectures, notes, or laboratory investigations.

NAME: _____ DATE: _____ PER: _____

BIOLOGY

Natural Selection and Speciation**READ RETRIEVE CONNECT & USE****Next Generation Sunshine State Standard**

SC.912.L.15.13: Describe the conditions required for natural selection, including: overproduction of offspring, inherited variation, and the struggle to survive, which result in differential reproductive success.

Common Core Scientific Literacy Standard

Determine the central ideas or conclusions of a text; trace the text's explanation or depiction of a complex process, phenomenon, or concept; provide an accurate summary of the text.

Birds Caught in the Act of Becoming a New Species

ScienceDaily (Dec. 8, 2011) — A study of South American songbirds completed by the Department of Biology at Queen's University and the Argentine Museum of Natural History, has discovered these birds differ dramatically in colour and song yet show very little genetic differences, indicating they are on the road to becoming a new species.

"One of Darwin's accomplishments was to show that species could change, that they were not the unaltered, immutable products of creation," says Leonardo Campagna, a Ph.-D biology student at the Argentine Museum of Natural History in Buenos Aires, who studied at Queen's as part of his thesis. "However it is only now, some 150 years after the publication of his most important work, *On the Origin of Species*, that we have the tools to begin to truly understand all of the stages that might lead to speciation which is the process by which an ancestral species divides into two or more new species."

For decades scientists have struggled to understand all of the varied forces that give rise to distinct species. Mr. Campagna and his research team studied a group of nine species of South American seedeaters (finches) to understand when and how they evolved.

The study found differences in male reproductive plumage and in some key aspects of the songs that they use to court females. Now, the group is looking to find the genes that underlie these differences, as these so-called candidate genes may well prove to be responsible for the evolution of a new species. This will allow researchers to gain insights into evolution.

"*Studies like ours teach us something about what species really are, what processes are involved and what might be lost if these and other species disappear.*"

Campagna's research co-supervisor is Stephen Loughheed, Acting Director of QUBS and an associate professor in the Department of Biology. QUBS has been a pivotal part of research and teaching at Queen's for more than six decades and hosts researchers from both Canadian and international institutions. Research at QUBS has resulted in more than 800 publications in peer-reviewed journals and more than 200 graduate and undergraduate theses.

The findings were recently published in the *Proceedings of The Royal Society*.

L. Campagna, P. Benites, S. C. Loughheed, D. A. Lijtmaer, A. S. Di Giacomo, M. D. Eaton, P. L. Tubaro. **Rapid phenotypic evolution during incipient speciation in a continental avian radiation.** *Proceedings of the Royal Society B: Biological Sciences*, 2011

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NAME: _____ DATE: _____ PER: _____

BIOLOGY

1. Read the article, "Birds Caught in the Act of Becoming a New Species?" After reading the article (5-10 minutes), write down everything you can remember in the box below. The process of recalling the information is important, so do not return to the article at this point.

2. Return to the article if necessary and answer the following questions. You may also need to draw from your knowledge of biology and you should feel free to use your text or other resource.

a) Describe Darwin's theory of natural selection.

b) Define speciation.

c) What is the relationship between natural selection and speciation?

d) Based on the article, identify the key evidence that suggests these birds are currently evolving into different species.

NAME: _____ DATE: _____ PER: _____

BIOLOGY

Protein Synthesis**READ RETRIEVE CONNECT & USE****Next Generation Sunshine State Standard**

SC.912.L.16.5: Explain the basic processes of transcription and translation, and how they result in the expression of genes.

Common Core Scientific Literacy Standard

Analyze the structure of the relationships among the concepts in a text, including the relationship among key terms.

Lift Weights, Eat Mustard, Build Muscles?

ScienceDaily (Sep. 29, 2011) — If you are looking to lean out, add muscle mass, and get ripped, a new research report published in *The FASEB Journal* suggests that you might want to look to your garden for a little help. That's because scientists have found that when a specific plant steroid was given orally to rats, it triggered a response similar to anabolic steroids, with minimal side effects. In addition, the research found that the stimulatory effect of homobrassinolide (a type of brassinosteroid found in plants such as mustards) on protein synthesis in muscle cells led to increases in lean body mass, muscle mass and physical performance.

"We hope that one day brassinosteroids may provide an effective, natural, and safe alternative for age- and disease-associated muscle loss, or be used to improve endurance and physical performance," said Slavko Komarnytsky, Ph.D., a researcher involved in the work from the Plants for Human Health Institute, FBNS at North Carolina State University in Kannapolis, N.C. "Because some plants we eat contain these compounds, like mustards, in the future we may be able to breed or engineer these plants for higher brassinosteroid content, thus producing functional foods that can treat or prevent diseases and increase physical performance."

To make this discovery, Komarnytsky and colleagues exposed rat skeletal muscle cells to different amounts of homobrassinolide and measured protein synthesis in cell culture. The result was increased protein synthesis and decreased protein degradation in these cells. Healthy rats then received oral administration of homobrassinolide daily for 24 days. Changes in body weight, food consumption, and body composition were measured. Rats receiving homobrassinolide gained more weight and slightly increased their food intake. Body composition was measured using dual-emission X-ray absorptiometry analysis and showed increased lean body mass in treated animals over those who were not treated. This study was repeated in rats fed high protein diet and similar results were observed. Additionally, researchers used surgically castrated peri-pubertal rat models to examine the ability of homobrassinolide to restore androgen-dependent tissues after androgen deprivation following castration. Results showed increased grip strength and an increase in the number and size of muscle fibers crucial for increased physical performance.

"The temptation is to see this discovery as another quick fix to help you go from fat to fit," said Gerald Weissmann, M.D., Editor-in-Chief of *The FASEB Journal*, "and to a very small degree, this may be true. In reality, however, this study identifies an important drug target for a wide range of conditions that cause muscle wasting."

D. Esposito, S. Komarnytsky, S. Shapses, I. Raskin. **Anabolic effect of plant brassinosteroid.** *The FASEB Journal*, 2011; 25 (10): 3708
DOI: 10.1096/fj.11-181271

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NAME: _____ DATE: _____ PER: _____

BIOLOGY

1. Read the article, "Lift weights, eat mustard, build muscles?" After reading the article (5-10 minutes), write down everything you can remember in the box below. The process of recalling the information is important, so do not return to the article at this point.

2. Return to the article if necessary and answer the following questions. You may also need to draw from your knowledge of biology and you should feel free to use your text or other resource.

a) What are the two main steps of protein synthesis and where in the cell do they take place?

b) What is the role of amino acids in translation?

c) Explain the relationship of transcription and translation to gene expression.

d) Based on the article, what were the independent and dependent variables in the study?

NAME: _____ DATE: _____ PER: _____

BIOLOGY

Enzymes**READ RETRIEVE CONNECT & USE****Next Generation Sunshine State Standard**

SC.912.L.18.11: Explain the role of enzymes as catalysts that lower the activation energy of biochemical reactions. Identify factors, such as pH and temperature, and their effect on enzyme activity.

Common Core Scientific Literacy Standard

Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.

Bacteria Use Caffeine as Food Source

ScienceDaily (May 25, 2011) — A new bacterium that uses caffeine for food has been discovered by a doctoral student at the University of Iowa. The bacterium uses newly discovered digestive enzymes to break down the caffeine, which allows it to live and grow.

"We have isolated a new caffeine-degrading bacterium, *Pseudomonas putida* CBB5, which breaks caffeine down into carbon dioxide and ammonia," says Ryan Summers, who presented his research at the 111th General Meeting of the American Society for Microbiology in New Orleans.

Caffeine itself is composed of carbon, nitrogen, hydrogen and oxygen, all of which are necessary for bacterial cell growth. Within the caffeine molecule are three structures, known as methyl groups, composed of 1 carbon and 3 hydrogens atoms. This bacterium is able to effectively remove these methyl groups (a process known as N-demethylation) and essentially live on caffeine.

Summers and his colleagues have identified the three enzymes responsible for the N-demethylation and the genes that code for these enzymes. Further testing showed that the compounds formed during break down of caffeine are natural building blocks for drugs used to treat asthma, improve blood flow and stabilize heart arrhythmias.

Currently these pharmaceuticals are difficult to synthesize chemically. Using CBB5 enzymes would allow for easier pharmaceutical production, thus lowering their cost. Another potential application is the decaffeination of coffee and tea as an alternative to harsh chemicals currently used.

"This work, for the first time, demonstrates the enzymes and genes utilized by bacteria to live on caffeine," says Summers.

University of Wisconsin-Madison (2010, October 31). Chemists concoct new agents to easily study critical cell proteins. *ScienceDaily*. Retrieved September 22, 2011, from <http://www.sciencedaily.com/releases/2010/10/101031154013.htm>

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NAME: _____ DATE: _____ PER: _____

BIOLOGY

1. Read the article, "Bacteria use caffeine as food source." After reading the article (5-10 minutes), write down everything you can remember in the box below. The process of recalling the information is important, so do not return to the article at this point.

2. Return to the article if necessary and answer the following questions. You may also need to draw from your knowledge of biology and you should feel free to use your text or other resource.

a) What is the primary function of enzymes?

b) What would happen to CBB5 if the bacteria were heated up? How might it affect the shape of the enzyme?

c) Why can't humans live off caffeine?

d) Using the article, identify three potential benefits of the CBB5 enzyme for humans.

NAME: _____ DATE: _____ PER: _____

Human Evolution**READ RETRIEVE CONNECT & USE****Next Generation Sunshine State Standard**

SC.912.L.15.10: Identify basic trends in hominid evolution from early ancestors six million years ago to modern humans, including brain size, jaw size, language, and manufacture of tools.

Common Core Scientific Literacy Standard

Compare and contrast findings presented in a text to those from other sources, noting when the findings support or contradict previous explanations or accounts.

New Kenyan Fossils Challenge Established Views On Early Evolution Of Our Genus Homo

ScienceDaily (Aug. 13, 2007) — Two new fossils, described this week in the journal *Nature*, cast fresh light on a little understood and important period of human prehistory at the dawn of our own genus, *Homo*. The new fossils were discovered by the Koobi Fora Research Project, an international group of scientists directed by mother-daughter team Meave and Louise Leakey, and affiliated with the National Museums of Kenya (NMK).

Human evolution over the last two million years is often portrayed as a linear succession of three species: *Homo habilis* to *Homo erectus* to ourselves, *Homo sapiens*. Of these, *Homo erectus* is commonly seen as the first human ancestor which is like us in many respects, but with a smaller brain. The new fossils are significant because both their relative geological ages and their physical attributes directly challenge these views about our human ancestry.

One of the two fossils, an upper jaw bone of *Homo habilis* (KNM-ER 42703), dates from 1.44 million years ago, which is more recent than previously known fossils of that species. This late-survivor shows that *Homo habilis* and *Homo erectus* lived side by side in eastern Africa for nearly half a million years. "Their co-existence makes it unlikely that *Homo erectus* evolved from *Homo habilis*," explains Meave Leakey, one of the lead authors of the paper. Instead, both species must have had their origins between 2 and 3 million years ago, a time from which few human fossils are known. "The fact that they stayed separate as individual species for a long time suggests that they had their own ecological niche, thus avoiding direct competition."

The second fossil (KNM-ER 42700), found in the same region of northern Kenya, is an exquisitely preserved skull of *Homo erectus*, dated to about 1.55 million years ago. "What is truly striking about this fossil is its size," says Fred Spoor, another lead author. "It is the smallest *Homo erectus* found thus far anywhere in the world."

Significantly, the variation in size of East African *Homo erectus* fossils, from the petite new skull to a large specimen discovered previously at Olduvai Gorge in neighbouring Tanzania, almost rivals that shown by modern gorillas. "In gorillas males are much larger than females, and this sexual dimorphism is related to their strategy of having multiple mates," observes co-author Susan Antón. "The new Kenyan fossil suggests that, contrary to common belief, this may have been true of *Homo erectus* as well." Because great sexual dimorphism is thought to be a primitive, or ancestral, feature during human evolution, the diminutive new find implies that *Homo erectus* was not as human-like as once thought.

Both human fossils were found during fieldwork in 2000, in the Ileret region, east of Lake Turkana. The *Homo erectus* skull was exceptionally well preserved, because it was still almost entirely encased in sandstone when it was initially spotted by NMK researcher Fredrick Manthi. Painstaking laboratory preparation at the NMK by Christopher Kiarie was required to free the fossil from its sediment. To establish the age of the two fossils, the geological layers were studied by Patrick Gathogo, Frank Brown, and Ian McDougall.

New York University (2007, August 13). New Kenyan Fossils Challenge Established Views On Early Evolution Of Our Genus Homo. *ScienceDaily*

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NAME: _____ DATE: _____ PER: _____

1. Read the article, "New Kenyan Fossils Challenge Established Views On Early Evolution Of Our Genus Homo" After reading the article (5-10 minutes), write down everything you can remember in the box below. The process of recalling the information is important, so do not return to the article at this point.

2. Return to the article if necessary and answer the following questions. You may also need to draw from your knowledge of biology and you should feel free to use your text or other resource.

a) List sequentially (from earliest to most recent) five ancestors of modern humans.

b) Identify some characteristics (physical or behavioral) that distinguish different species of hominids.

c) Contrast skull and brain size among hominid species with modern humans.

d) How does information on human evolution in your text contrast with the information in the article? Why might there be these differences?

NAME: _____ DATE: _____ PER: _____

BIOLOGY

READ RETRIEVE CONNECT & USE**Invasive Species****Next Generation Sunshine State Standard**

SC.912.L.17.8: Recognize the consequences of the losses of biodiversity due to catastrophic events, climate changes, human activity, and the introduction of invasive, non-native species.

Common Core Scientific Literacy Standard

Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.

Sea Urchins Cannot Control Invasive Seaweeds

ScienceDaily (July 13, 2011) — Exotic marine species, including giant seaweeds, are spreading fast, with harmful effects on native species, and are increasingly affecting the biodiversity of the Mediterranean seabed. Some native species, such as sea urchins (*Paracentrotus lividus*), can fight off this invasion, but only during its early stages, or when seaweed densities are very low.

Spanish researchers have carried out a study to look at the ability of sea urchins (*Paracentrotus lividus*) -- generalist herbivores that live in the Mediterranean -- to limit the invasion of two introduced seaweeds (*Lophocladia lallemandii* and *Caulerpa racemosa*), which are having a "grave" effect on the seabed. "After seven months of experimentation, we found that predation by these herbivores had no effect once *Caulerpa racemosa* was completely established, although it did reduce the degree to which it became established in the very early stages of invasion," Emma Cebrián, lead author of the study and a researcher in the Department of Environmental Sciences at the University of Girona, said.

In the case of *Lophocladia lallemandii*, the sea urchins were able to limit the seasonal spread of the seaweed. "Since the amount of this species directly consumed by the sea urchins is very low, this reduction was due more to the decline in other native species (consumed by the sea urchins), which act as a substrate for the seaweed," the expert explains.

The research, which has been published in *Biological Invasions*, shows that, although high sea urchin densities can have a limiting effect on the establishment of invasive seaweeds, "they exert no control whatsoever in highly invaded areas," the researcher adds.

The researchers used the experiment to compare the proportion of invasive seaweeds in the environment and the amount actually consumed (present in sea urchin stomach contents). "The sea urchins do not consume the invasive species according to their availability -- they have preferences," says Cebrián. Although the two species of invasive seaweed are very abundant in the environment, "*Lophocladia lallemandii* was consumed to a very low degree, while the sea urchins displayed a certain preference for eating *Caulerpa racemosa*," the biologist goes on.

To find out whether consumption by the sea urchins could control the invasion by these two species, the team of researchers placed large numbers of sea urchins into cages (12 sea urchins/m²) and monitored how the invasive seaweeds developed. The cages were placed in areas completely invaded by *C. racemosa* (established invasion), in areas where the invasion was still very limited (initial stages of invasion) and in places where *L. lallemandii* was very abundant. "The sea urchins only controlled the expansion of *C. racemosa* in the cages in places where the invasion was still at a very early stage," Cebrián points out.

The research team says it would "be of great interest" to study possible mechanisms for controlling these invasions, and the resistance of native communities to them, given the growing impact of exotic species.

Cebrián, Emma; Ballesteros, Enric; Linares, Cristina; Tomas, Fiona. Do native herbivores provide resistance to Mediterranean marine bioinvasions? A seaweed example. *Biological Invasions*, 13(6): 1397-1408, June 2011

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BIOLOGY

1. Read the article, "Sea urchins cannot control invasive seaweeds." After reading the article (5-10 minutes), write down everything you can remember in the box below. The process of recalling the information is important, so do not return to the article at this point.

2. Return to the article if necessary and answer the following questions. You may also need to draw from your knowledge of biology and you should feel free to use your text or other resource.

a) Identify a potential negative impact of an invasive/exotic species on a native species.

b) What is meant by the term "generalist herbivore?"

c) Based on the study, at what stage of seaweed invasion are sea urchins beneficial in controlling the spread?

d) Using the article, identify the independent and dependent variables of this study.

NAME: _____ DATE: _____ PER: _____

BIOLOGY

Mutations**READ RETRIEVE CONNECT & USE****Next Generation Sunshine State Standard**

SC.912.L.16.4: Explain how mutations in the DNA sequence may or may not result in phenotypic change. Explain how mutations in gametes may result in phenotypic changes in offspring.

Common Core Scientific Literacy Standard

Determine the central ideas or conclusions of a text; trace the text's explanation or depiction of a complex process, phenomenon, or concept; provide an accurate summary of the text.

Mechanism Behind Cleft Palate Development Identified

ScienceDaily (Sep. 29, 2010) — Researchers from Mount Sinai School of Medicine have found a new mechanism that explains why a certain gene mutation causes craniofrontonasal syndrome (CFNS), a disorder that causes cleft palate and other malformations in the face, brain, and skeleton. Cleft palate affects one of every 1,000 newborns.

The research is published in the September 15 issue of *Genes & Development*.

Previous research has shown that a mutation in a gene called ephrin-B1 caused abnormalities in facial development, but researchers were uncertain of how. Philippe M. Soriano, PhD, Professor, Developmental and Regenerative Biology, and Jeffrey O. Bush, PhD, Postdoctoral Fellow, Developmental and Regenerative Biology, both at Mount Sinai School of Medicine, studied mice embryos that were genetically engineered to have a mutation in the ephrin-B1 gene. They determined that ephrin-B1 controls craniofacial development by signaling cells to multiply. When there is a mutation in this gene, it causes anomalies in the cell proliferation process.

"Common thinking has been that ephrin-B1 only guided cells in craniofacial development," said Dr. Soriano. "We were surprised to learn that, instead, this gene signals for cells to multiply, providing us with a clear understanding of why craniofacial development is abnormal when a mutation is present."

Drs. Bush and Soriano also wanted to determine why females with one normal copy of the ephrin-B1 gene are more severely malformed than males who have no copy of the gene at all. They found that female mice embryos with this type of mutation had a so-called "mosaic" cell proliferation, meaning cell multiplication is disrupted in some areas while developing normally in others. This creates abnormal craniofacial development.

"Craniofacial anomalies are among the most common human birth defect," said Dr. Bush. "Our findings represent a critical step forward in understanding how cleft palate and other malformations develop, and will hopefully bring us closer to finding ways to prevent or treat these abnormalities."

Drs. Bush and Soriano plan to study ephrin-B1 further by identifying which molecules work in conjunction with it and how. Gaining a further understanding of the signaling mechanisms of this gene will likely lead to designing prevention and treatment strategies.

The Mount Sinai Hospital / Mount Sinai School of Medicine (2010, September 29). Mechanis behind cleft palate development identified. *ScienceDaily*. Retrieved September 10, 2011, from <http://www.sciencedaily.com/releases/2010/09/100914171317.htm>

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NAME: _____ DATE: _____ PER: _____
BIOLOGY

1. Read the article, "Mechanism behind cleft palate development identified." After reading the article (5-10 minutes), write down everything you can remember in the box below. The process of recalling the information is important, so do not return to the article at this point.

2. Return to the article if necessary and answer the following questions. You may also need to draw from your knowledge of biology and you should feel free to use your text or other resource.

a) What is a mutation?

b) List the different types of mutation.

c) Why does a mutation in the ephrin-B1 gene result in a cleft palate or other facial deformities?

d) Summarize the main points of the article in 3-5 sentences.

NAME: _____ DATE: _____ PER: _____

Populations and Carrying Capacity**READ RETRIEVE CONNECT & USE****Next Generation Sunshine State Standard**

SC.912.L.17.5: Analyze how population size is determined by births, deaths, immigration, emigration, and limiting factors (biotic and abiotic) that determine carrying capacity.

Common Core Scientific Literacy Standard

Analyze the structure of relationships among concepts in a text, including relationships among key terms..

Presence Of Wolves Allows Aspen Recovery In Yellowstone

ScienceDaily (July 26, 2007) — The wolves are back, and for the first time in more than 50 years, young aspen trees are growing again in the northern range of Yellowstone National Park.

The findings of a new study, just published in *Biological Conservation*, show that a process called "the ecology of fear" is at work, a balance has been restored to an important natural ecosystem, and aspen trees are surviving elk browsing for the first time in decades.

The research, done by forestry researchers at Oregon State University, supports theories about "trophic cascades" of ecological damage that can be caused when key predators -- in this case, wolves -- are removed from an ecosystem, and show that recovery is possible when the predators are returned. The results are especially encouraging for the health of America's first national park, but may also have implications for other areas of the West and other important predators.

After an absence of 70 years, wolves were re-introduced to Yellowstone Park in 1995, and elk populations began a steady decline, cut in half over the past decade. Also, the presence of a natural predator appears to have altered the behavior of the remaining elk, which in their fear of wolves tend to avoid browsing in certain areas where they feel most vulnerable. The two factors together have caused a significant reduction in elk browsing on young aspen shoots, allowing them to survive to heights where some are now above the animal browsing level.

The OSU researchers say they believe there are two forces at work -- both the lower populations of elk, and their changed behavior due to fear of wolves -- but it's difficult to determine exactly which force is the most significant.

"In riparian zones, where wolves can most easily sneak up on elk, and gullies or other features make it more difficult for elk to escape, we've seen the most aspen recovery," Ripple said. "We did not document nearly as much recovery in upland areas, at least so far, where elk apparently feel safer. But even there, aspen are growing better in areas with logs or debris that would make it more difficult for elk to move quickly."

This element of fear, the OSU scientists said, is a concept that is now getting more attention in ecology -- it factors in not just the numbers or species of animals, but also their behavior and the reasons for that behavior. Predators such as wolves or cougars, OSU researchers have shown, have the ability to strike fear into their prey and significantly change their behavior as a result.

Oregon State University (2007, July 26). Presence Of Wolves Allows Aspen Recovery In Yellowstone. *ScienceDaily*.

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NAME: _____ DATE: _____ PER: _____

1. Read the article, "Presence Of Wolves Allows Aspen Recovery In Yellowstone." After reading the article (5-10 minutes), write down everything you can remember in the box below. The process of recalling the information is important, so do not return to the article at this point.

2. Return to the article if necessary and answer the following questions. You may also need to draw from your knowledge of biology and you should feel free to use your text or other resource.

a) Identify at least two biotic factors that influence elk population size.

b) How did the removal of wolves from Yellowstone result in a decreased population of aspen trees?

c) Why are elk grazing less on young aspen trees in riparian (near streams and rivers) zones?

d) How does the "ecology of fear" act as a limiting factor on the elk population?

APPENDIX B

Read Retrieve, Connect and Use and Implementation Guide

READ RETRIEVE CONNECT & USETM

FAQ

What is RRCU?

Read, Retrieve, Connect and Use (RRCU) is designed to improve student achievement in science by emphasizing content and developing informational text reading skills. Each RRCU is a single page, front and back module that includes an informational text passage, a retrieval activity, and questions designed to build reading comprehension. Passages are selected for grade-level appropriateness, interest, and salient connections to course content. RRCU is a straight-forward method for increasing reading opportunities in science courses without taking away time from content teaching.

Does RRCU connect to the Florida State Next Generation Sunshine State Science Standards?

Each RRCU focuses on a single core science standard, identified clearly at the top of the page for both student and teacher.

Does RRCU connect the Common Core Standards for Scientific Literacy?

Each RRCU identifies one Common Core Reading Standard for Science and Technical Texts to be addressed by the module, clearly identified at the top of the page for both student and teacher.

Who developed RRCU?

Read, Retrieve, Connect and Use began in the classroom of Kerryane Monahan, a high school biology teacher and National Board Certified Teacher. RRCU has been modified and improved with the help of Cristina Veresan, a former middle school science teacher and current K-12 Science Curriculum Supervisor for St. Lucie Public Schools. Ms. Monahan is now studying the impact of RRCU on student achievement as part of her doctoral work.

Is RRCU based on research?

Yes, it is! The retrieval study technique has been shown by Karpicke (2010) to improve student learning and retention over other methods such as repeated studying and concept mapping. RRCU also employs connecting to background knowledge and summarizing to improve reading comprehension, both of which have been shown as effective strategies in the literature. RRCU is currently being studied to examine its impact on student science achievement.

READ RETRIEVE CONNECT & USE™

IDEAS FOR IMPLEMENTATION

Read, Retrieve, Connect and Use (RRCU) is probably best used as a method of formative assessment after teaching and learning has taken place on the standard being addressed. But in some cases, you may be able to use it as a “hook” to introduce a new topic, particularly if students already have had some background in a previous course. RRCU can also serve as an excellent mechanism for review prior to testing or as closing activities in block classes.

- Start with a whole class KWL on the board. Lead the class (or have a student) in collecting what students already know about the topic of the standard and write in the K column. Identify areas that need further study in the W column. Now have students complete the RRCU and afterwards complete the L column.
- Consider having students work in small groups to complete the RRCU, particularly if you have mixed ability classes. Students can collectively write what they remember from the text and then work together to answer the questions.
- For struggling readers, you might want to read aloud and have them follow along underlining/circling key words and ideas.
- For higher-level classes, you might assign as homework. Time permitting, you could start the read and retrieve portion in class and have students complete the second half for homework.
- Use the articles to start discussions about scientific research, experimental design, and scientific processes.
- Write the main idea from the article on the board and get students to shout out connections from class until you’ve covered the whole board. This is a great way to remind students about how earlier material might connect in with current topics.
- Create your own RRCU with articles that are grade-level appropriate, scientifically-based and interesting or odd to best engage students. Remember to focus on the standards to guide both your article choice and question development.
- Once higher-level students are familiar with RRCU modules, challenge students to create an RRCU themselves (locate text and design questions) and administer to classmates.
- Enrich the RRCU by projecting photos of the text subjects or other visual material relating to the content.

APPENDIX C

DATA TABLE FOR STUDENTS INCLUDING DEMOGRAPHIC AND TEST SCORES

Teacher	Student	Grade	Gender	Ethnicity	LEP	SWD	ED	FCAT Read	Bio Pretest	Bio Q1	Bio Q2	Bio Q3	LA Pretest	LA Q1	LA Q2	LA Q3	Group
T4	S1	10	10	H	N	Y	Y	284	33	37	38	53	25	59	60	53	0
T4	S2	10	10	B	N	N	Y	275	36	46	40	23	56	52	47	43	0
T4	S3	10	10	B	N	Y	Y	216	26	40	38	35	34	45	47	30	0
T4	S4	10	10	B	N	N	Y	348	50	43	76	65	56	79	73	77	0
T4	S5	10	10	W	N	N	N	319	29	46	56	35	53	31	63	60	0
T4	S6	10	10	H	N	N	Y	327	24	71	66	63	53	45	40	57	0
T4	S7	10	10	B	N	N	Y	296	19	31	40	38	47	48	50	57	0
T4	S8	10	10	B	N	N	Y	262	24	31	40	35	69	52	43	27	0
T4	S9	10	10	B	N	Y	Y	240	26	31	36	35	34	38	60	60	0
T4	S10	10	10	H	N	N	Y	349	36	46	68	68	69	59	67	77	0
T4	S11	10	10	W	N	N	Y	372	50	43	58	65	66	66	83	73	0
T4	S12	10	10	W	N	N	N	333	36	51	52	53	72	66	57	70	0
T4	S13	10	10	B	N	Y	Y	277	17	40	40	35	44	34	47	40	0
T4	S14	10	10	W	N	N	Y	315	38	60	50	25	63	34	77	53	0
T4	S15	10	10	H	N	N	Y	285	26	54	66	78	53	48	50	63	0
T4	S16	10	10	B	N	Y	N	280	45	34	34	33	59	45	40	53	0
T4	S17	10	10	W	N	N	N	279	26	49	40	35	28	31	53	37	0
T4	S18	10	10	B	N	N	Y	319	38	43	60	48	72	66	53	57	0
T4	S19	10	10	H	N	N	Y	364	52	71	64	78	72	72	70	73	0
T4	S20	10	10	H	N	Y	Y	326	43	60	58	48	72	62	67	73	0
T4	S21	10	10	W	N	N	N	310	33	46	40	45	63	38	60	60	0
T4	S22	10	10	H	N	N	Y	284	17	31	46	35	47	45	33	30	0
T4	S23	10	10	H	N	N	Y	317	36	60	44	33	47	41	83	53	0
T4	S24	10	10	B	N	N	Y	338	26	60	58	50	56	59	70	47	0
T4	S25	10	10	B	N	Y	Y	286	19	34	26	33	38	31	33	50	0
T4	S26	10	10	W	N	N	N	339	45	57	64	63	75	62	70	57	0
T4	S27	10	10	W	N	N	N	388	48	57	80	65	72	69	70	70	0
T4	S28	10	10	B	N	N	Y	314	29	37	42	58	72	59	63	67	0
T4	S29	10	10	B	N	N	Y	330	57	49	54	48	63	69	73	47	0
T4	S30	10	10	A	N	N	N	298	29	43	42	35	63	52	57	43	0
T4	S31	10	10	W	N	N	N	320	43	49	58	70	72	66	63	67	0

T4	S32	10	10	W	N	N	Y	341	50	51	56	25	72	62	60	63	0
T4	S33	10	10	W	N	N	Y	303	48	54	58	60	66	62	57	67	0
T4	S34	10	10	W	N	N	N	384	43	60	76	63	69	83	80	67	0
T4	S35	10	10	H	N	Y	Y	262	31	26	32	40	59	45	47	43	0
T4	S36	10	10	B	N	N	Y	268	12	46	42	45	56	31	50	53	0
T4	S37	10	10	B	N	N	N	305	33	51	58	28	44	52	63	63	0
T4	S38	10	10	B	N	Y	Y	267	21	23	20	30	41	31	53	33	0
T4	S39	10	10	W	N	N	Y	350	48	69	56	65	78	90	80	80	0
T4	S40	10	10	W	N	N	N	337	55	83	80	78	84	59	73	73	0
T4	S41	10	10	H	N	N	Y	300	24	54	54	30	53	69	63	53	0
T4	S42	10	10	B	N	N	N	277	38	57	58	55	56	55	67	60	0
T4	S43	10	10	A	N	N	Y	290	33	34	40	40	66	31	60	47	0
T4	S44	10	10	B	N	Y	Y	240	29	46	36	43	41	55	50	60	0
T4	S45	10	10	B	N	N	Y	309	40	60	60	43	66	48	73	63	0
T4	S46	10	10	B	N	N	Y	321	38	43	48	58	59	79	63	63	0
T4	S47	10	10	B	N	N	Y	321	31	51	54	60	59	62	80	67	0
T4	S48	10	10	W	N	N	N	359	60	54	72	73	75	79	80	80	0
T4	S49	10	10	H	N	N	Y	283	14	60	50	48	44	41	57	50	0
T4	S50	10	10	M	N	N	N	321	40	37	54	48	59	52	60	47	0
T4	S51	10	10	W	N	N	Y	299	29	51	50	25	59	48	60	60	0
T4	S52	10	10	A	N	N	Y	335	33	51	62	65	72	55	70	67	0
T4	S53	10	10	B	N	N	N	276	29	31	30	25	47	21	40	40	0
T4	S54	10	10	B	N	N	Y	281	38	43	30	45	38	55	40	57	0
T4	S55	10	10	B	N	N	Y	317	36	60	66	53	72	72	77	57	0
T4	S56	10	10	B	N	N	Y	326	38	57	66	48	75	69	67	63	0
T4	S57	10	10	B	N	Y	Y	130	38	46	42	20	47	38	23	27	0
T4	S58	10	10	H	N	N	Y	302	26	40	40	45	56	59	83	60	0
T4	S59	10	10	W	N	N	N	370	62	57	72	68	81	69	77	73	0
T4	S60	10	10	H	N	N	Y	392	62	60	76	83	84	66	70	63	0
T4	S61	10	10	B	N	N	N	311	43	63	62	55	75	62	63	63	0
T4	S62	10	10	B	N	N	Y	282	26	43	48	50	66	59	67	63	0
T4	S63	10	10	W	N	N	Y	424	60	71	80	80	88	72	73	80	0
T4	S64	10	10	B	N	N	Y	328	50	54	62	65	88	62	73	70	0
T4	S65	10	10	B	N	N	Y	318	48	63	72	58	56	72	63	57	0
T4	S66	10	10	W	N	N	N	355	62	63	78	70	75	72	77	70	0
T4	S67	10	10	W	N	N	Y	381	43	34	48	45	75	55	77	77	0
T4	S68	10	10	W	N	N	Y	252	38	31	46	48	56	55	70	60	0
T4	S69	10	10	B	N	N	Y	303	33	31	58	40	66	69	70	57	0
T4	S70	10	10	W	N	N	Y	341	55	54	64	75	69	76	60	80	0
T4	S71	10	10	M	N	N	Y	334	36	49	56	45	75	59	73	70	0
T4	S72	10	10	W	N	N	Y	364	48	74	66	55	84	79	60	67	0

T4	S73	10	10	H	N	N	N	316	26	54	58	58	69	66	70	60	0
T4	S74	10	10	B	N	N	Y	288	31	29	54	40	59	69	67	47	0
T4	S75	10	10	B	N	Y	Y	322	29	51	42	58	19	21	67	47	0
T4	S76	10	10	H	N	N	N	292	36	37	30	40	56	62	73	33	0
T4	S77	10	10	W	N	N	Y	348	36	51	56	48	84	62	63	73	0
T4	S78	10	10	W	N	N	N	293	24	43	54	38	59	41	37	53	0
T4	S79	10	10	W	N	N	N	322	31	46	40	40	59	28	70	53	0
T4	S80	10	10	B	N	N	Y	202	29	29	30	28	44	17	43	37	0
T5	S81	10	10	W	N	N	Y	243	36	43	34	35	44	55	63	40	0
T5	S82	10	10	W	N	N	Y	304	14	31	66	40	66	52	57	43	0
T5	S83	10	10	W	N	N	Y	346	57	69	64	63	63	62	77	67	0
T5	S84	10	10	B	N	N	Y	311	43	63	52	53	38	52	63	70	0
T5	S85	10	10	B	N	N	N	220	29	26	36	35	28	55	43	47	0
T1	S86	10	10	B	N	N	Y	388	76	83	86	90	81	66	63	80	1
T1	S87	10	10	B	N	N	Y	312	21	43	66	53	50	59	63	70	1
T1	S88	10	10	W	N	N	Y	313	33	40	54	53	59	69	63	53	1
T1	S89	10	10	H	N	N	Y	191	31	23	30	18	16	21	20	37	1
T1	S90	10	10	W	N	Y	N	326	38	51	54	38	69	69	33	57	1
T1	S91	10	10	H	N	N	Y	290	36	46	40	40	56	52	70	57	1
T1	S92	10	10	H	N	N	Y	328	48	54	46	63	56	76	67	63	1
T1	S93	10	10	B	N	N	Y	256	36	34	36	30	56	45	57	47	1
T1	S94	10	10	W	N	N	Y	250	29	29	24	28	56	38	53	47	1
T1	S95	10	10	H	N	N	Y	270	31	37	18	25	56	52	67	33	1
T1	S96	10	10	M	N	N	Y	279	38	40	40	25	47	62	40	60	1
T1	S97	10	10	W	N	N	N	327	38	46	52	63	75	76	63	70	1
T1	S98	10	10	H	N	N	Y	331	29	43	82	58	66	59	67	73	1
T1	S99	10	10	B	N	N	Y	302	21	46	44	23	66	52	60	63	1
T1	S100	10	10	B	N	N	Y	281	26	40	38	33	66	55	57	40	1
T1	S101	10	10	B	N	N	Y	307	36	66	68	48	75	72	70	53	1
T1	S102	10	10	H	N	N	Y	292	36	34	28	23	41	52	43	30	1
T1	S103	10	10	B	N	N	Y	291	33	54	28	33	50	55	67	57	1
T1	S104	10	10	W	N	N	N	324	21	51	46	40	72	69	67	47	1
T1	S105	10	10	B	N	Y	Y	272	14	34	30	23	22	38	33	43	1
T1	S106	10	10	H	N	N	Y	237	38	23	24	33	34	31	60	63	1
T1	S107	10	10	B	N	N	Y	322	29	37	62	43	63	52	60	60	1
T1	S108	10	10	H	N	N	Y	295	26	43	38	33	56	48	80	67	1
T1	S109	10	10	H	N	N	Y	304	38	43	18	18	28	38	17	23	1
T1	S110	10	10	I	N	N	Y	369	36	54	64	55	84	66	73	73	1
T1	S111	10	10	W	N	N	N	277	29	20	26	30	34	52	30	43	1
T1	S112	10	10	H	N	N	Y	307	31	40	60	45	56	59	60	70	1
T1	S113	10	10	B	N	N	Y	288	21	31	50	38	53	55	40	67	1

T1	S114	10	10	H	N	N	Y	388	45	71	80	45	78	69	73	73	1
T1	S115	10	10	H	N	N	Y	291	52	40	44	33	59	59	77	63	1
T1	S116	10	10	W	N	N	Y	307	48	34	46	55	66	62	73	40	1
T1	S117	10	10	H	N	N	Y	309	31	57	64	55	72	41	67	67	1
T1	S118	10	10	B	N	Y	Y	253	29	40	36	45	50	34	63	23	1
T1	S119	10	10	B	N	N	N	343	55	66	78	63	66	52	77	63	1
T1	S120	10	10	B	N	N	Y	352	36	43	36	40	50	48	53	57	1
T1	S121	10	10	B	N	N	N	288	40	34	40	45	88	55	57	60	1
T1	S122	10	10	B	N	N	Y	279	19	31	56	23	53	24	67	60	1
T1	S123	10	10	B	N	N	Y	274	38	49	52	45	50	52	47	43	1
T1	S124	10	10	B	N	N	Y	276	31	54	42	25	47	48	60	47	1
T1	S125	10	10	B	N	N	Y	290	31	29	34	25	56	59	57	47	1
T1	S126	10	10	B	N	N	Y	293	14	46	36	40	66	59	63	43	1
T1	S127	10	10	W	N	N	Y	286	33	40	60	45	22	52	67	43	1
T1	S128	10	10	B	N	N	Y	289	31	20	44	35	69	66	67	53	1
T1	S129	10	10	B	N	N	Y	263	12	26	28	30	41	41	53	43	1
T1	S130	10	10	W	N	N	Y	275	38	54	56	45	66	59	53	53	1
T1	S131	10	10	H	N	N	N	309	29	71	64	43	69	76	80	80	1
T1	S132	10	10	B	N	N	Y	308	33	40	44	43	66	76	77	63	1
T1	S133	10	10	B	N	N	Y	257	48	26	34	23	59	41	50	60	1
T1	S134	10	10	W	N	N	Y	331	33	69	60	45	66	66	73	63	1
T1	S135	10	10	B	N	Y	Y	188	21	29	32	33	41	38	30	20	1
T1	S136	10	10	H	N	N	N	317	21	60	52	45	66	45	63	70	1
T1	S137	10	10	W	N	N	N	309	38			20	75	59	70	67	1
T1	S138	10	10	W	N	N	Y	296	31	37	36	33	50	59	57	63	1
T1	S139	10	10	H	N	N	Y	317	19	40	38	28	47	66	53	50	1
T1	S140	10	10	B	N	N	Y	282	36	29	46	25	63	48	33	47	1
T1	S141	10	10	H	N	N	Y	309	50	57	50	58	63	62	77	77	1
T1	S142	10	10	M	N	N	N	322	55	69	82	73	59	62	73	70	1
T1	S143	10	10	M	N	N	Y	258	12	40	36	40	53	59	57	60	1
T1	S144	10	10	W	N	N	N	371	50	77	70	50	72	79	80	67	1
T1	S145	10	10	H	N	N	N	309	26	49	52	45	63	55	60	60	1
T1	S146	10	10	W	N	N	N	275	40	37	56	40	66	69	70	47	1
T1	S147	10	10	H	N	Y	Y	340	48	49	46	48	66	55	70	70	1
T1	S148	10	10	W	N	Y	Y	212	17	29	28	38	38	28	13	23	1
T1	S149	10	10	B	N	N	Y	342	43	74	62	58	72	76	80	67	1
T1	S150	10	10	W	N	N	Y	318	40	49	66	50	63	45	60	77	1
T1	S151	10	10	B	N	N	Y	249	31	31	50	33	56	34	47	67	1
T1	S152	10	10	H	N	N	Y	286	38	37	60	55	69	45	67	63	1
T1	S153	10	10	H	N	N	Y	298	31	46	44	38	72	59	63	60	1
T1	S154	10	10	B	N	N	Y	335	26	57	56	53	81	69	70	63	1

T1	S155	10	10	H	N	Y	N	330	29	31	30	45	59	38	63	60	1
T1	S156	10	10	W	N	N	Y	367	57	83	74	65	84	69	73	63	1
T1	S157	10	10	A	N	N	Y	342	38	54	58	30	63	59	73	77	1
T1	S158	10	10	B	N	N	N	350	38	63	66	58	84	79	73	77	1
T1	S159	10	10	H	N	N	Y	242	24	46	46	25	38	38	47	43	1
T1	S160	10	10	B	N	N	Y	262	33	43	52	58	53	66	60	43	1
T1	S161	10	10	B	N	N	Y	307	29	46	58	60	69	72	60	67	1
T1	S162	10	10	H	N	N	Y	317	29	40	50	35	56	48	53	57	1
T1	S163	10	10	H	N	N	Y	301	19	31	40	30	59	59	80	63	1
T1	S164	10	10	B	N	Y	N	243	17	40	44	30	38	41	33	37	1
T1	S165	10	10	B	N	N	N	292	29	34	30	28	69	41	37	40	1
T1	S166	10	10	H	N	N	Y	298	33	37	18	33	59	48	53	63	1
T1	S167	10	10	H	N	N	N	310	52	71	76	60	69	66	73	70	1
T1	S168	10	10	H	N	Y	Y	321	31	34	48	45	44	66	40	63	1
T1	S169	10	10	B	N	N	Y	325	48	63	74	60	78	66	83	70	1
T1	S170	10	10	B	N	N	Y	323	24	66	54	50	53	55	43	70	1
T1	S171	10	10	H	N	N	Y	342	38	60	72	55	72	69	67	67	1
T1	S172	10	10	B	N	N	N	300	33	46	64	50	47	62	53	63	1
T1	S173	10	10	H	N	Y	Y	228	29	26	36	18	25	14	27	30	1
T1	S174	10	10	H	N	N	Y	287	38	37	40	35	56	55	60	43	1
T1	S175	10	10	H	N	N	Y	253	36	49	36	23	38	55	73	50	1
T1	S176	10	10	B	N	N	Y	266	31	49	58	38	53	48	53	47	1
T1	S177	10	10	B	N	N	Y	306	31	46	42	43	50	59	73	63	1
T1	S178	10	10	W	N	N	Y	291	33	37	56	33	66	59	33	60	1
T1	S179	10	10	B	N	N	Y	155	17	31	24	20	28	28	27	40	1
T1	S180	10	10	W	N	N	Y	361	52	80	88	85	75	69	73	67	1
T1	S181	10	10	H	N	Y	Y	266	12	31	28	30	38	41	57	27	1
T1	S182	10	10	W	N	N	Y	297	31	43	50	30	38	48	53	43	1
T1	S183	10	10	B	N	N	N	302	17	63	44	38	56	59	63	70	1
T1	S184	10	10	H	N	N	Y	291	26	34	64	38	44	59	47	50	1
T1	S185	10	10	W	N	N	N	310	43	51	60	43	78	52	60	47	1
T2	S186	10	10	B	N	N	Y	319	33	57	46	55	56	62	63	63	1
T2	S187	10	10	B	N	N	Y	325	38	40	34	53	66	41	50	70	1
T2	S188	10	10	H	N	N	Y	324	50	54	58	35	81	52	77	73	1
T2	S189	10	10	W	N	N	Y	297	36	34	32	35	0	34	47	37	1
T2	S190	10	10	H	N	N	N	235	24	43	46	58	50	38	57	63	1
T2	S191	10	10	B	N	N	Y	345	57	60	78	70	84	79	73	67	1
T2	S192	10	10	B	N	N	Y	337	21	60	64	50	41	76	67	77	1
T2	S193	10	10	B	N	N	Y	303	38	60	58	53	72	69	73	67	1
T2	S194	10	10	B	N	N	Y	346	29	63	58	30	41	34	67	53	1
T2	S195	10	10	B	N	N	Y	304	19	46	46	40	28	24	33	53	1

T2	S196	10	10	H	N	N	Y	366	52	69	76	83	56	79	70	83	1
T2	S197	10	10	B	N	N	Y	337	43	51	56	48	78	62	67	77	1
T2	S198	10	10	B	N	N	N	342	43	60	68	53	66	69	73	73	1
T2	S199	10	10	W	N	N	N	345	62	71	82	75	78	52	77	80	1
T2	S200	10	10	W	N	N	N	338	45	60	44	58	78	72	70	70	1
T2	S201	10	10	W	N	N	Y	313	40	46	54	58	63	62	77	47	1
T2	S202	10	10	B	N	N	N	328	45	43	52	60	69	72	63	77	1
T2	S203	10	10	H	N	N	Y	293	38	54	50	33	50	62	73	67	1
T2	S204	10	10	H	N	N	Y	322	60	77	60	70	72	59	63	50	1
T2	S205	10	10	B	N	N	Y	304	31	49	50	60	53	59	47	70	1
T2	S206	10	10	B	N	N	Y	364	48	74	74	55	81	59	70	60	1
T2	S207	10	10	H	N	N	Y	340	31	46	52	38	72	48	70	57	1
T2	S208	10	10	B	N	N	Y	321	38	57	66	45	31	69	67	63	1
T2	S209	10	10	H	Y	N	Y	232	24	34	50	40	22	69	60	47	1
T2	S210	10	10	W	N	N	Y	251	40	43	30	33	50	45	67	40	1
T2	S211	10	10	B	N	N	Y	324	26	57	66	60	63	72	73	67	1
T2	S212	10	10	W	N	N	N	332	40	60	74	70	72	52	60	60	1
T2	S213	10	10	A	Y	N	N	269	36	49	60	45	41	34	53	53	1
T2	S214	10	10	W	Y	N	Y	241	26	23	58	38	25	28	37	37	1
T2	S215	10	10	W	N	N	Y	355	50	60	70	55	78	59	77	70	1
T2	S216	10	10	B	Y	N	Y	202	33	26	44	50	41	55	47	43	1
T2	S217	10	10	B	Y	N	Y	266	21	37	44	28	50	45	60	47	1
T2	S218	10	10	H	N	N	Y	343	19	57	54	48	63	72	57	50	1
T2	S219	10	10	B	N	N	Y	303	26	46	42	50	59	69	50	60	1
T2	S220	10	10	B	N	N	N	298	33	40	70	40	41	62	40	70	1
T4	S221	9	9	W	N	N	N	356	73	68	77	87					1
T4	S222	9	9	W	N	N	N	343	63	44	50	63					1
T4	S223	9	9	W	N	N	Y	367	87	78	77	93					1
T4	S224	9	9	W	N	N	N	322	53	76	60	90					1
T4	S225	9	9	W	N	N	Y	342	83	80	63	77					1
T4	S226	9	9	W	N	N	N	376	80	66	70	93					1
T4	S227	9	9	H	N	N	N	361	83	74	67	77					1
T4	S228	9	9	W	N	N	N	364	73	80	73	67					1
T4	S229	9	9	W	N	N	N	380	87	76	80	93					1
T4	S230	9	9	A	N	N	N	324	73	60	77	73					1
T4	S231	9	9	H	N	N	Y	331	70	74	77	90					1
T4	S232	9	9	W	N	N	Y	373	80	78	77	87					1
T4	S233	9	9	W	N	N	N	338	63	78	57	90					1
T4	S234	9	9	W	N	N	N	373	77	80	80	90					1
T3	S235	10	10	H	N	N	Y	309		54	44	48					1
T3	S236	10	10	H	N	N	Y	307		60	24	50					1

T3	S237	10	10	W	N	N	Y	300		49	48	33					1
T3	S238	10	10	W	N	N	Y	309		60	34	23					1
T3	S239	10	10	W	N	N	N	301		9	50	45					1
T3	S240	10	10	W	N	N	Y	326		54	48	20					1
T3	S241	10	10	B	N	N	Y	275		34	26	33					1
T3	S242	10	10	H	N	N	Y	297		54	44	38					1
T3	S243	10	10	B	Y	N	N	214		37	36	30					1
T3	S244	10	10	W	N	N	N	378		54	66	60					1
T3	S245	10	10	W	N	N	Y	309		49	46	35					1
T3	S246	10	10	H	N	N	Y	309		34	48	38					1
T3	S247	10	10	W	Y	N	N	273		40	40	40					1

APPENDIX D

Normality Test and Descriptive Data for Language Arts Benchmark Test Scores

Descriptive Statistics and Normality Test Results for Language Arts Data				
	LA Pre-test	LA Quarter 1	LA Quarter 2	LA Post-test
N	220	220	220	220
Mean	58.413	55.304	60.418	57.527
Median	59.000	59.000	63.000	60.000
Mode	56.000	59.000	73.000	63.000
Std Deviation	15.951	14.422	14.131	13.582
Std error of the mean	1.075	0.972	0.952	0.915
Skewness	-0.601	-0.453	-0.856	-0.518
Variance	254.435	208.011	199.687	184.496
Kurtosis	0.259	-0.1778	0.426	-0.288
Uncorrected SS	806395	718445	846810	768470
Corrected SS	55721.359	45554.596	43731.527	40404.8364
Coefficient Variation	27.307	26.078	23.388	23.611
Range	88.000	76.000	70.000	63.000

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Group