The influence of improved literacy on understanding in high school biology Using specific strategies to improve literacy and science comprehension

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One of the current trends in education is towards the increase of literacy in all disciplines, science in particular. The purpose of this study was to investigate if the incorporation of literacy strategies, both reading and writing, would promote understanding in science students. A group of ninth grade students in a biology class were studied over the course of 2 months. During the course of the study an array of different literacy strategies were implemented in the classroom. Many students who initially struggled with reading and writing became more comfortable and were able to comprehend and express this comprehension more clearly. The positive correlation between understanding and literacy supports the implementation of literacy in science.

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One of the current trends in education is towards the increase of literacy in all disciplines, science in particular. The purpose of this study was to investigate if the incorporation of literacy strategies, both reading and writing, would promote understanding in science students. A group of ninth grade students in a biology class were studied over the course of 2 months. During the course of the study an array of different literacy strategies were implemented in the classroom. Many students who initially struggled with reading and writing became more comfortable and were able to comprehend and express this comprehension more clearly. The positive correlation between understanding and literacy supports the implementation of literacy in science.
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The influence of improved literacy on understanding in high school biology

Literacy in schools has been one of the areas of focus and concern for at least the last decade. Many schools have gone so far as to hire literacy specialists to help teachers integrate literacy into their instruction. It was once thought that literacy was strictly the job of English teachers and other teachers would become frustrated when students fell short in reading and writing in their content areas.

In the Rush-Henrietta Central School District, and many other districts across the state and country, literacy across content areas has become an area of high priority. This district wide initiative includes all content areas and has additional strength in science. Literacy is often ignored in the traditional science curriculum yet is an essential part of understanding in science. Without the ability to process information and convey this information to others it becomes nearly impossible to understand and demonstrate understanding in science.

Research has shown both the importance of literacy in science but also the benefits that improved literacy has on science comprehension. To truly improve literacy in science abilities concerning both reading and writing must be addressed. However, these skills are different in science than in other disciplines. In order to improve literacy in science specific and complicated vocabulary must be understood and utilized, formats of laboratory reports must be recognized, and skills must be honed in making connections between different components and variables. All of these different traits must be taught in conjunction with the science curriculum which can appear to be a daunting task.

Many literacy improvement strategies have common principles and goals. After a lengthy review of the research some of these goals have been discussed and will be
implemented in an attempt to improve the literacy skills of ninth grade biology students. The intended outcomes of the process will be that students use reading and writing as tools to increase the amount of higher order thinking and comprehension about topics in biology. Regardless of the specific outcomes students should benefit from focused attention on literacy skills that will transfer to their other academic coursework.

Literature Review

There has been extensive research done in the field of literacy during the past decade. The literature reviewed will demonstrate the importance of literacy in the discipline of biology. The importance of literacy in understanding biological concepts is widely accepted by researchers and educational experts. Strategies for both reading and writing have been used to improve literacy most of which with remarkable results. The literature will show that these strategies not only help with understanding of science, but have a plethora of additional benefits.

Importance of Literacy

One of the primary goals of teaching science has always been to help students become scientifically literate and lifelong science learners. Researchers and educators alike have found that it is crucially important for students to learn the skills necessary to make decisions based on the information that is presented to them (Dlugokieniski & Sampson, 2008). Without the skills needed to make informed decisions students cannot hope to truly understand scientific issues. Literacy has been used as a tool to help students learn independently without the help of a teacher or other authority figure telling them what is and is not important. Reading itself has repeatedly proven to be a necessary but complex skill, and reading for understanding and critical analysis is even more
complex (Dlugokienski & Sampson). Research has also found that reading primary literature is a valuable skill in science. This literature is often dense and takes a special set of literacy skills in order to read (Janick-Buckner, 1997). Although not all students will encounter primary literature literacy skills are still important for reading the work of others and communicating their own ideas as well. Without the skills to interpret the work of others and pass on their own ideas they can never hope to contribute to the discussions of the scientific community (Dlugokienski & Sampson).

Another reason that researchers have found literacy important to learning science is simply due to the fact that most students have in the past had to read and gather information from a science textbook. Supported by both Chiappetta and Fillman (2007) and Radcliffe, Caverly, Peterson, and Emmons (2004) textbooks have been used by more than three quarters of the students taking high school science classes. To expect students to learn science without a set of literacy skills is erroneous in the presence of this information. "At all levels of schooling Science textbooks are often used as the primary organizer of the subject matter that students are expected to master and provide detailed explanations of topics to be taught" (Chiappetta & Fillman, p. 1847). Students have used textbooks in many different subjects for decades, but science textbooks have always been a different type of textbook. Filled with dense and specific information science textbooks are almost reference books with comprehension questions imbedded in the pages. It is nearly impossible for students to learn the skills necessary to read science texts in an English class. "Students need to be introduced to the various genres of science writing," says Dlugokienski (2008, p. 15). All of the research was consistent in voicing the necessity for specific literacy skills in order to become proficient in science.
Impediments to literacy

For both teachers and students research has shown major issues that prevent the learning of certain literacy skills. These problems ranged from text selection to prior knowledge to simple difficulties in the implementation of reading and writing. One of the primary concerns found by researchers was that teachers claimed it was too difficult to and time consuming to schedule literacy strategies into the curriculum. It was found that the perception of many teachers is that because writing strategies involve the coordination of two disciplines, science and English, that it took more time and energy than they were able to give (Baker, et al., 2008). Researchers agreed that the workload of teachers was already high, but it was the fashion in which they taught that caused some of the problems. However, Lance and Lance (2006) suggested that teachers are simply focusing on an incorrect perception of what increased literacy entails. They found that often teachers would assign more writing assignments without increasing the amount of instructional time dedicated to the practice of sound writing. Perhaps this was based on a misunderstanding of the necessary instructional rigor needed to teach writing in science or perhaps it was due to the fact that instructors simply did not care to take the necessary time to teach writing because it was outside their field. Regardless of the cause it was shown that teachers often had a negative attitude towards literacy. Baker, et al. found that this negative attitude may have been caused by teachers feeling uncomfortable with teaching writing since it was outside of their content specialty area. Teachers needed to feel comfortable with the idea of teaching literacy before it can be successfully implemented in the classroom.
Many other impediments to literacy instruction were found other than teachers' attitudes and abilities. For instance finding and appropriately using text was often found to cause a number of problems. One of the factors found to be difficult in science reading was the style of the text itself. At time when reading primary literature students were confused about the structure of the paper which prevented them from understanding the content of the paper (Brill, Falk, & Yarden, 2004). When coherence was occluded by text style and structure it was incredibly difficult for students to understand. In conjunction with this issue was the issue that teachers had with even selecting appropriate text. Teachers needed to look for suitable texts, whether books or articles, that would remedy such issues. The process of selecting text is very arduous and time consuming which was part of the objection raised by Baker et al. (2008). Muench (2000) found that there were certain questions that could be asked as criteria for selecting appropriate texts. While this information was used for undergraduate course it could easily be applied to high school science courses. The general information asked by the questions detailed the educational goals of the course and specific assignment, the concepts to be understood by the reader, and additional information that could be gained from the reading (Muench). These questions were certainly used for the benefit of the students reading the text, but what the article fails to include is the time it took to utilize each of these criteria in the selection of literature. While many people may believe that finding appropriate articles may be an easy part of the process it was found that it certainly could be one of the most time consuming parts.

Aside from the issues with teachers and text, the ultimate focus for the improvement of literacy is the students. Students were found to be one of the very
enigmatic pieces of the puzzle. There were a multitude of issues found that students face which inhibit their acquisition of literacy skills. Not the least of these issues was the attitudes not of the teachers, but of the students themselves. Students were often found to object because they believed the purpose of science was not found in writing. "Usually, this concern is encountered not because the writing tasks are difficult, but because the students have not been given adequate instruction in writing content and forms" (Baker, et al., 2008, p. 107). The problems of attitude were rooted in students' lack of literacy skills within the specific content. Writing and reading skills alike are found to be issues preventing students from learning. Often encountered in reading and asked for in writing were science specific terms that are not found in daily language. Students found that this scientific language inhibited their understanding of the text because understanding the terms was crucial for understanding the text (Brill, Falk, & Yarden, 2004). When the students understood the language the frequently encountered another problem. The other major problem encountered by students is the contradiction between their prior knowledge and the information found in the text. One specific example cited by Brill, Falk and Yarden described how a student could not understand a segment of text dealing with genetically engineered viruses because it was apparently in contradiction of information learned during tenth grade science. These impediments of the students are only a few of the more common problems found by researchers that inhibit literacy in science.

Writing as a Learning tool

With the importance of literacy to science instruction readily apparent it is necessary to develop strategies to combat all of the obstacles facing literacy instruction.
The first set of strategies reviewed were geared entirely towards using writing, both improving it and using it as a learning tool. Both of these types of strategies were proven very useful to improve student understanding.

Many researchers agree that writing can be used very well as a learning tool instead of simply a way of communicating information. Writing has been found to associate very closely with cognitive processes (Gunel, Hand, & McDermott, 2009). By writing these concepts and thoughts down in writing, teachers were able to view students' cognitive processes as they reasoned and justified their way through the assignment. The improvement in these cognitive processes through writing can also produce and improvement in achievement in school. While the improvements in school performance associated with writing have been shown to be small, they were consistently positive (Banger-Drowns, Hurley, & Wilkinson, 2004). Writing has also proven itself valuable as a predictor of students' abilities. Gunel, Hand, and McDermott analyzed student writing and found that performance on written assignments was a very good predictor of the students' scores on the end of the unit assessment.

Not only have these written assignments be used to view student understanding and predict student success, they have also been shown to improve students cognitive skills. "Writing promotes critical-thinking skills and construction of vital scientific concepts and challenges ingrained misconceptions" (Baker, et al., 2008, p. 105). Improvement of cognitive skills may be the most important goal of education as a whole since the inception of the modern educational system. Gunel, Hand, and McDermott agree by saying "writing-to-learn activities help students gain conceptual understanding scientific topics" (p. 364). While both of these articles agreed that writing can improve
conceptual knowledge, they fail to elaborate on the specific knowledge they are discussing. Other research done has provided some specific areas are improved by writing. Among these cognitive benefits were the ability to make connections, synthesis of new ideas, exploring relations, and possibly the most important self-reflection of overall topic comprehension (Banger-Drowns, Hurley, & Wilkinson, 2004). With each of these cognitive skills being honed through writing it is necessary for a number of strategies to be utilized to improve writing skills.

Numerous strategies to both improve writing and use writing as a learning tool have been researched and evaluated. Among these strategies were a number of different styles of writing that could be used for various outcomes. Lance and Lance (2006) offered a number of different short writing assignments. These brief assignments included journals, entrance and exit slips, and short topical essays; each of these assignments offered a different set of benefits for students.

Journaling may be one of the most widely reviewed strategies focused on the improvement of writing for students. Ackerson and Young stated it best by saying, "there is perhaps no better place than a science journal for students to develop informational writing skills" (2005, p. 38). Literature has shown there are many different academic uses for journals, all of which were shown to be highly beneficial for students. One of the beneficial uses of journals reviewed was as a management tool for larger projects (Lance & Lance, 2006). Students used the journals to document their progress on the project by including entries about the topic chosen, literature chosen to support their topic, and general entries about the progress of the project. This strategy allowed students to think and reflect on their own work and allowed the teacher to check on the progress of the
students without constantly watching over them. Journaling can also be a way that students keep track of all of their writing so they can revisit earlier work as they continue to progress. The journal has been used as a tool to record observations, organize data, and draw inferences based upon the previously written observations (Ackerson & Young). These two concepts could easily be integrated so that students were recording both their data and inferences, and reflecting upon their progress in one place. Another slightly different use for journals was a metacognitive evaluation for the students' use (Banger-Drowns, Hurley, & Wilkinson, 2004). This use was strictly for students to write down and comment on the topics being covered during class. In this way they were able to reflect on their own understanding and pose questions to be asked or researched later. All of these strategies correlated with strong student comprehension and each could be useful independently or in conjunction with the others.

Another very valuable type of writing discussed by Lance and Lance (2006) is the topical essay. Commonly used as an assessment tool by many instructors the topical essay has been found to engage students in active learning as they create meaning through their work. Often instruction in this area has been neglected, but if given properly this simple task could help students draw new conclusions, analyze information, and synthesize new ideas that would increase their understanding. In addition to proper instruction the use of an appropriate prompt was essential. One specific type of prompt found to be very powerful was the refutation of a misconception (Dlugokienski & Sampson, 2008). When used correctly the prompts have proven a powerful learning tool; the key is that they were used correctly. In order to maximize the potential of the writing prompt Dlugokienski and Sampson provided a set of criteria to follow as the prompt is
created. They stated it was necessary to include the information needed by the students about topic, audience, purpose, etc., and to outline the steps that needed to be taken in the writing process. Their focus on refutational prompts also provided students with the motivation to write. The basic essay that is used daily by teachers across the country has been given an entirely new perspective when viewed through the lens of these authors.

Lengthy and ongoing writing is not the only valuable form of writing that can be used in the classroom. Some of the most valuable writing discussed by researchers are short assignments that have tremendous value for students. One of these strategies reviewed by Ackerson and Young (2005) is the use of observation and inference charts. While this strategy was designed for younger students and was simplistic in nature it still had value as a written assignment. By writing the observations students were able to organize their data then able to analyze it to generate inferences about that information. This is a skill that is useful in all of science and can be made sharper simply by writing the process down. Another set of very brief assignments with value are short fiction and nonfiction activities. These activities discussed by Straits (2005) were designed for younger children, but once again still could be used for middle school and high school students. Some of the assignments used by Straits were fictional stories using vocabulary words, writing an accurate, topic specific poem or riddle, writing facts researched about a specific topic, and creating a concept map. All of these techniques are short but can be used to help students understand the content they are investigating through creative and nontraditional writing. These researchers have shown that even short written assignments can be useful for increasing student understanding.
Writing strategies

Regardless of the vehicle used for writing there still must be a check of quality to ensure learning can occur. Strategies are needed to improve student writing in order for understanding about content and the writing process to be achieved. Two strategies that have been revealed to be very helpful are peer reviews and the use of grading rubrics. Each of these tools was shown to have a positive impact on the quality of writing produced by students.

Rubrics have exhibited a number of valuable purposes in education. Teachers have commonly used rubrics to assess student work, writing in particular. There are many other educationally valuable ways that rubrics have also been used. Lance and Lance (2006), and Dlugokienki and Sampson (2008) agreed that it was necessary for students to be aware of how they would be assessed on their writing assignments through the use of a rubric. The rubrics allowed students to understand the way in which they would be graded, thus improving their writing by having specific guidelines to use as a reference. It has provided a way for teachers to emphasize important aspects of assignments by showing the students that something like the synthesis or analysis of ideas is worth a higher point value than other parts of the written work (Lance & Lance). This has also been a way of creating consistency between the outcome desired by the teacher and the product created by the student. An additional benefit was that it "enable[d] teachers to examine the strengths and weaknesses of their curriculum and methods of instruction" (Dlugokienki & Sampson, p. 18). It has shown that when rubrics were used correctly that they we not only an assessment tool, but a tool to improve student writing.
An additional student centered strategy that has demonstrated a positive impact on student writing was the use of peer reviews. In stark contrast to the end of the line process of teacher editing, or grading as it is commonly called, peer reviewing allows students to not only assess the work of their peers, but allows them to take a different perspective on their own work. Lance and Lance (2006) cautioned that this process needed to be taught or scaffolded by the teacher initially. When properly implemented peer review allowed students to increase their proficiency of reading their own work and allowed them to develop a greater understanding of how content area composition should appear. Peer review could easily be used in conjunction with grading rubrics to allow students to assess each other based upon criteria provided by the instructor. This would also allow students to look at their own work and become reflective about their own writing process.

Regardless of which writing strategies are used it has been displayed that improved writing can and does have a positive impact on student understanding. Whether students are writing in a journal, a topical essay based on a writing prompt, or just a short assignment all of these techniques have shown positive benefits for student learning. When these writing assignments are used in conjunction with the editing and reviewing strategies discussed they become an even more powerful learning tool.

*Types of literature*

The second and equally as important part of literacy is reading comprehension. Students must be able to read and understand material from within the curriculum or they will not be able to fully succeed in mastering the course material. Just as was the case for writing strategies there were also a wide range of reading strategies that have been tried
and discussed by professionals in the education field. These strategies included choosing different types of text, lengthy multi-step strategies, and small repetitive strategies.

Text choice may be one of the simplest influences on students' desire and ability to read. Almost every science classroom both past and present uses some form of a textbook to drive or accompany instruction. "High school biology textbooks are major curriculum resources that provide the subject matter content for a great deal of what is taught in biology classrooms, and to some degree how content is taught" (Chiappetta & Fillman, 2007, p. 1863). When analyzed, there were some common traits that existed in many of the prominently used biology textbooks. Some of the basic components found in the textbooks were discussions about science, short activities meant to engage students, laboratory experiments, illustrations, and recent topics dealing with new technologies and societal impacts (Chiappetta & Fillman). This vast amount of knowledge and content certainly can be a valuable text resource to students in a biology class. However the analysis by Chiappetta and Fillman did find that there was one area where textbooks frequently fell through of their intended goals. They found that textbooks frequently struggled in taking students' prior knowledge into account. This is a very difficult task to accomplish because students all possess such different types and amounts of prior knowledge. Lack of association with prior knowledge may seem like a minor setback but if has been frequently shown to greatly inhibit the ability of a student to comprehend their reading. Even though this problem was found there was a very positive result of the analysis of the textbooks. Research showed that textbooks are now better equipped to teach biology as a method of investigation about the world instead of simply presenting a static body of knowledge (Chiappetta & Fillman). This information makes an even
stronger case for the use of textbooks in biology classrooms. If the textbook is for some reason the only text available to be utilized it can still serve as a method of improving the literacy skills of the students using it.

Often textbooks are not the only literature available for students in science. Using many other sources has also proven useful for students. A very reasonable alternative investigated was the use of short books, both fiction and nonfiction, as sources of information. Short books had one very distinct advantage over a textbook which was the fact that students could read strictly about a topic that engaged them (Brassell, 2006; Bircher, 2009). The anecdotal research done by Brassell pertained specifically to third grade students, however it could easily be translated to older students. Books with varying degrees of difficulty were used to attract students' attention. Students were allowed to read books of any level and it was found they often picked the challenging books as they became more confident readers. Improvements in literacy skills were allowed to happen naturally as students became more comfortable with reading about science related content throughout the year. In similar research Bircher (2009) found that allowing students to read juvenile books, meant for students up to grade nine, increased their reading fluency. One of the other benefits of reading books was that students were exposed to curriculum specific vocabulary in an extracurricular book (Brassell).

Vocabulary is among the most challenging parts of learning to read in science, so by introducing vocabulary with more familiar contextual clues the research showed that students were able to learn and become more comfortable with the technical vocabulary used in class. Using simple books from the school library could serve as an invaluable resource to help students improve their reading skills in science.
Not only can students read books in the classroom, they can read primary literature. Much of this literature is very dense and would require direct instruction about the ways in which it should be read. However this does not mean it cannot be another valuable resource for a science class, especially when focusing on enrichment of a certain topic. One of the keys to success of this strategy revealed by the literature is the selection of appropriate primary research articles by the teacher. "Choosing appropriate research articles, processing those articles, and reading them in a way that enables the students to interact with them, are all mean of facilitating high-school students' understanding of the content of research articles" (Yarden, Brill, & Falk, 2001, p. 194). Reading primary research literature has been shown to require and improve a certain set of literacy skills crucial to science. Some of the skills discussed are understanding the foundation of a research plan, familiarization of scientific language, understanding of the methods scientists use to solve problems, and an overall understanding of the scientific research process (Yarden, Brill, & Falk). These skills are not easy to acquire and hone. Often it is necessary for teachers to provide instruction about how to read a primary research article since it is very different from the typical reading assignment. A skill that was proven crucial is the ability to analyze the figures included in the text (Schinske, Clayman, Busch, & Tanner, 2008). Analysis of the figures in a paper has been shown to increase comprehension of the remaining content of the literature. This type of analysis can also translate to figures found in other places such as the Living Environment Regents Exam given by New York State. One of the additional benefits found by the research was that students at times took a personal interest in the research by identifying with the researcher (Yarden, Brill, & Falk). This connection can be a very powerful factor in
getting students interested in scientific reading. If they become engaged with the content it will often lead to increased comprehension of the topic at hand. Schinske, Clayman, Busch, and Tanner found similar positive results due to student engagement with the articles. Reading scientific articles can have an overwhelming positive effect on student learning especially regarding the way in which they read. Primary research also "enables student exposure tot he professional scientific world" to which they would otherwise not be privaleged" (Yarden, Brill, & Falk, p. 194).

All types of text can be helpful as tools to improve literacy in the science classroom. Textbooks are almost always available, but other books and primary articles are also not difficult to find. When utilized properly each of these types of literature can improve the reading abilities and overall topic comprehension of students.

Reading Strategies

Using diverse, pertinent types of literature are important, but the skills required to read and comprehend this text may be more important. Educators have been using a variety of strategies to improve student reading for years. Some of these strategies are complex systems for reading while others are simple and repetitive strategies. Research has shown that many of these strategies can be exceptionally helpful in improving the literacy skills of students in a science classroom.

There are two overarching, ongoing literacy strategies reviewed in the literature, the PLAN strategy (Radcliffe, Caverly, Peterson, & Emmons, 2004) and the CREATE strategy (Hoskins, Stevens, & Nehm, 2007). Each of these strategies proved to have similar components and goals with some variation in the methods. The implementation of either one of these strategies would have to be a year long process used for each reading
done in the class. CREATE is an acronym that stands for consider, read, elucidate hypotheses, analyze and interpret data, and think of the next experiment (Hoskins, Stevens, & Nehm). This process was specifically used for reading primary literature but could be adapted slightly for any type of literature. The purpose of the CREATE strategy was to generate a style of active reading for the students. As active readers students were capable of increasing their understanding of the content and increasing their interest in the articles they are reading. Active reading is also the goal of the PLAN strategy which stands for predict the content and construct a concept map, locate known and unknown information on the map, add notes during reading, and note new understandings (Radcliffe, Caverly, Peterson, & Emmons). The largest difference between this strategy and the CREATE strategy was that it was meant for textbook reading although it also could be modified for different forms of text. Research done by Radcliffe, Caverly, Peterson and Emmons showed that after only four weeks of using the PLAN strategy there was a noticeable increase in the use of higher level thinking. Even though each of these strategies used different methods and were intended for different types of literature the overall goal was the same. The key to both of these strategies was to produce active reading and higher order thinking by the students. This not only allowed students to understand the material better, but it also allowed them to improve their ability to read science specific literature.

Other strategies reviewed were intended to improve student reading of scientific literature were far less complex but were arguably just as effective. One of these highly effective strategies was connecting literature with the students' prior knowledge. Defined earlier as one of the chief problems with student comprehension prior knowledge is the
foundation on which student understanding is built. In fact it was found that prior knowledge is a more accurate predictor of text comprehension than the skill level of the reader (Ozuru, Dempsey, & McNamara, 2009). Anecdotal evidence confirming this position agreed that lack of prior knowledge can be difficult to overcome while the use of prior knowledge can increase comprehension (Brill, Falk, & Yarden, 2004). By simply engaging students prior knowledge they were able to increase their understanding of new material. Prior knowledge can also be gained from literature and used to increase understanding during instruction. A case study by VanHoewyk (2007) demonstrated that reading can be used to increase prior knowledge so that complex topics can be covered in class. When given a reading pertaining to cell division prior to instruction students already had a solid understanding of the facts that were going to be presented in the lecture (Van Hoewyk). There are many different ways to engage students prior knowledge such as basic pre-readings, anticipation guides, or a plethora of other reading strategies. All of these simple tools can be used to activate or increase the prior knowledge of students before reading.

Another strategy that helped students understand and improve their reading skills is the jigsaw reading. It is a form of cooperative learning in which students read different short sections of text then teach each other about the section they read. "The jigsaw activity can accommodate any focus topic that is debated in the literature. And this exercise made students active participants in their own and each other's learning" (Choe & Drennan, 2001, p. 329). Once again this strategy just like the others reviewed was intended to promote active reading and learning. This strategy also promotes a sense of responsibility in students because each student becomes solely responsible for reporting
about their portion of reading and their insights about the reading. It also helps students understand because their initial reading can be done with a small group that can read and discuss their findings with each other. This is a way to clear up misconceptions or misinformation by one student by having classmates explain the errors in comprehension.

One of the strategies reviewed actually appears slightly juvenile, but was found by many researchers to be beneficial to student understanding. The read aloud was used in younger classrooms, but can be valuable into middle school and early high school. As the name suggests the read aloud was just that, reading text out loud as a class. Reading aloud to students is beneficial in engaging them even students in high school become engaged when someone read aloud to them. It is also very advantageous for students who struggle with reading for various reasons. English language learners, low achieving students and students who identify themselves as auditory learners found reading aloud in class particularly beneficial (Bircher, 2009). Brassell (2006) adds that students became more confident in their own ability to read independently after the read aloud. Teachers may be reluctant to use a strategy such as a read aloud because it seems juvenile or a waste of time, but as the research has shown this was a very rewarding strategy for a number of different students.

A final and somewhat unorthodox strategy used is the open book test. This strategy could serve a purpose as a literacy skill assessment as well as a content assessment. The ability to locate information is sometimes as valuable of a skill as memorizing the information itself. In one study students were told at the onset of the semester that the completion of reading assignments would be crucially important. During class time the professor discussed "strategies for effectively and efficiently using
the textbook" (Phillips, 2006, p. 575). Some of these strategies included using text cues to identify key concepts and vocabulary words. By imbedding literacy instruction in the curriculum and assessments teachers were able to see the progress of students in both content knowledge and academic skills.

All of the strategies used to improve reading skills had certain components in common with one another. Each one of the strategies changed reading from a passive endeavor to an active one. This active type of reading provided much more understanding and promoted high order thinking of the information. Using any one of these strategies could prove and invaluable asset to teaching literacy and teaching science.

Summary

Literacy is everywhere in education and the science classroom is no exception to that rule. It is crucial that students be able to create meaning from reading and convey meaning in writing. The research showed how overwhelmingly important literacy is to the acquisition of scientific content knowledge. Researchers have also demonstrated the value in many different literacy strategies that could be used to improve both reading and writing in science. The benefits of an increase in literacy skills were unquestionable. These benefits extend not only through the science curriculum but to the rest of the students' academic endeavors.

Methodology

The study was conducted for the purpose of improving literacy in biology students. Based upon the literature there were specific areas of focus allowing students to target weaknesses in their ability to read and write for comprehension. These strategies
centered around an active form of reading and writing which was intended to allow students to interact with text thus creating greater meaning through reading and writing.

Participants

Participants for the study were 93 ninth grade students in a suburban school district. The school building at which the study was conducted was separated from the high school and housed only ninth grade students. Students ranged in age from thirteen to fifteen, the majority was at least fourteen at the time of the study. The students were separated into four sections of a biology class by the school administration. Since Biology has a laboratory requirement each class meets four out of six days during the schedule rotation.

Each of the sections was broken up by specific demographic groups and while it made each class similar it also made each class unique. Section one met during first block, from 7:40 AM until 9:05 AM, and consisted of twenty-six students. Of these twenty-six students eight were male and eighteen were female. Ethnically the class was broken into four groups, nineteen students were white, four were black, two were Asian and one was Hispanic. Section two met during second block, from 9:09 AM until 10:29 AM, and consisted of twenty-two students. Of these twenty-two students twelve were male and ten were female. Ethnically the class was broken into three groups, eighteen students were white, three were black and one was Asian. Section three met during blocks four and five, from 11:09 AM until 12:29 PM, and consisted of nineteen students. Of these nineteen students ten were male and nine were female. Ethnically the class was broken into three groups, fifteen students were white, three students were black, and one was Hispanic. The fourth and final section met three out of six days during blocks six and
seven, from 12:33 PM until 1:53 PM, and met one of the remaining three days during block two. The fourth section consisted of twenty-six students, fifteen male and eleven female. These twenty-six students were divided into four ethnic groups, twenty students were white, four were Asian, one was black, and one was Hispanic. One of these Asian students in the fourth section was an English language learner which proved particularly interesting when working on the improvement of literacy skills. Even though these classes and students can be classified by gender and ethnic category it is truly of little significance in relation to students' varying levels of academic ability.

Materials

Many of the materials used during the study were similar but specific to the intended assignment and lesson. Like many classes one of the primary sources of literature was the classroom textbook. The textbook used was the Prentice Hall Biology textbook written by Levine and Miller and published by Pearson Education. This was used in limited fashion because the reading level was above the grade level of the students.

One set of materials that were used on a frequent basis were a set of magazines called Current Science. Approximately once a month a new edition of Current Science, published by the Weekly Reader Corporation, was received by the science department for use in the classrooms. These magazines had a wide array of articles dealing with many of the topics in the Biology curriculum. Since the reading level of the articles were appropriate for ninth grade students they were used as supplemental reading materials to enrich students' abilities.
Other published materials were used to enhance the writing ability of the students. Each year, part C of the New York State Living Environment Regents exam contains at least one short answer question that students need to write about. These questions were used as writing prompts for the students to improve their writing skills. Other unpublished materials were used in the implementation of the study each specific to a topic of study.

Data Collection

There were various methods of data collection used throughout this study to determine if students had a change in comprehension ability after improving their literacy skills. In order to monitor students' literacy skills and content comprehension a baseline reading and writing level needed to be established for each student. At the beginning of the study each student, as part of the curriculum, was given a writing assignment and a reading assignment in order to establish a starting point in the process of learning (see Appendices A and B for examples of the initial assessments). Periodically students had their work assessed in this same fashion to monitor their progress towards improvement. The final assessment (as seen in Appendix G) was compared to their previous assessments and tested for clarity, writing and reading ability, and comprehension.

In addition to monitoring student progress through these on demand reading and writing assignments, the study was also monitored by reflective journal entries by the teacher. These entries consist primarily of observations about the apparent comprehension level of the students and the ability to convey this comprehension in writing. In addition to these observations about student progress there were also observations written regarding the strategies and implementation of these strategies. Each
of the entries were revisited after the writing of the subsequent entries. This allowed for reflection about student progress and effectiveness of each strategy used to improve literacy skills. These forms of assessment proved accurate indicators of the improvements made in science comprehension through the improvement of literacy skills.

One additional piece of data collected after the conclusion of the study will be the scores of the students on the New York State Living Environment Regents exam. This final assessment of student comprehension is standardized for every student in New York and will provide the data reviewed which is ultimately utilized by the state to determine comprehension.

Procedure

Much of the procedure involved instruction targeted at specific topics and imbedded into the classroom instruction. It occurred over the course of approximately half of a school year. The study began in the beginning of November and ended in January, although the methods used for instruction will continue for the remainder of the school year. This specific time frame was chosen for two reasons, it gave adequate time for students to show growth in literacy and comprehension, and it allowed for enough of the strategies to be implemented to influence the students.

Since each one of the classes met four out of the six days in the rotational schedule the strategies used to increase literacy were implemented on a regular basis during those four days. During each six day cycle at least one writing strategy and one reading strategy where used. These strategies ranged in complexity based upon the topics being covered and the materials available. Each strategy that was chosen was derived
from the literature and has shown merit in improving the literacy skills and comprehension of students.

There were three primary strategies used that dealt with the improvement of student writing. The first of these three strategies was the use of rubrics designed specifically for student work as see in Appendix D. One general rubric was used to guide student writing and there were slight modifications to this rubric as was necessary to coordinate with specific assignments. Students were given the rubric before the writing assignment which allowed them to evaluate the purpose and the desired learning outcomes of the assignment. Upon completion of the writing task the same rubric was used to evaluate the student work.

Often in conjunction with the rubrics was the use of peer reviewing strategies. In general students wrote a draft of their composition then swapped with other students and review each other's work, primarily for accuracy and fluidity. Students then had their work returned and edited the work based on the corrections of their classmates. This strategy was implemented in a variety of ways, but all followed the general format previous described. Some of the variations included blind editing in which students edited a composition without knowledge of the author, multiple peer editions, and team or co-editing.

The final specific writing strategy implemented in the study was the use of small topical essays. Frequently students believe that writing means either a one sentence response or an entire research paper. By using the short topical essays students were able to see writing from a new perspective. An example of a topical essay assignment can be found in Appendix C. These short essays were implemented both with and without use of
the other writing strategies previously mentioned. This particular strategy was convenient to fit into classroom instruction because it was not time consuming and allowed for multiple topics to be covered with short compositions to demonstrate understanding.

As noted previously, writing was only one component of the study, the other was reading. There were five separate strategies that were used to help students comprehend literature in the study. One of the strategies used was not used repetitively because it was in essence an instructional piece. In the literature was mention of a breakdown of a scientific article, for this study this concept was adapted to a Biology textbook. During the initial uses of the textbook instruction was given about how to read and interpret specific features of the textbook that would aid in comprehension. Students read along as the teacher read aloud and pointed out specific text attributes that could help students glean information. This set the stage for students to use the textbook for the remainder of the study without further struggles to inhibit the tasks presented to them.

In addition to the textbook students were frequently asked to read outside sources of information pertaining to the various topics of study. Many of these articles were found in the magazine *Current Science* which allowed students to read about specific content while reading at a level appropriate to their grade. These outside readings were used during class either as a warm up exercise or imbedded within instruction of the lesson. One example of the reading guides for these articles can be found in Appendix F. Each reading was followed by either a series of questions or a class discussion to determine the level of comprehension.

One of the other strategies used in the study was already mentioned during the decoding of the textbook and was used at times in association with the magazine articles
and other sources; this strategy was reading aloud. This was done in many different ways throughout the study some involving the teacher and some involving only the students. Frequently the reading began with the teacher then branched out so other students could read aloud as well. Other times the teacher or students began reading and the students finished reading independently.

The literature indicated the importance of activating prior knowledge of the students when reading. Activation of prior knowledge was the basis for many small strategies used prior to reading during the study. There were multiple variations of this idea. Sometimes students were shown short video clips, either academically or entertainment oriented, prior to reading that associated the reading with information of which students were already aware. Other times short questionnaires were used to activate students' prior knowledge. These questions were frequently based on strong opinions about a topic to which the students needed to pick one side to align their beliefs with. This introduced an emotional connection to the literature as well. At times the readings themselves were used to activate prior knowledge about other readings. For instance an article was used to prepare students for a reading in the textbook.

The last strategy used for the study was called a jigsaw. Students would break up into groups read a section of text with that group, then split up and report their information to another group. This was implemented frequently with longer textbook reading assignments (see Appendix E for an example). It allowed students to take responsibility for and deeply understand a section of text which was then conveyed to their classmates. Another variation of this strategy was that students broke into groups and all read the same material except each was asked to form a different opinion or look
at a different angle of the literature. When students reported out to the other groups they were able to discuss the same text from different perspectives to gain deeper understanding.

The implementation of this study was somewhat nebulous, but was performed this way with specific intentions in mind. By imbedding these strategies into the classroom setting it allowed students to continue to learn without the knowledge of a study being performed. This allowed for the removal of intentional bias from the study. Although repeating this study exactly is nearly impossible, it is very possible to replicate the use and frequency of use of the strategies.

Results

Three forms of data were collected and analyzed as part of this study. The first and most objective of these was the change in student attitude and perspective towards science literacy. The final two forms of data while still objective were the most important to the study; these were the change in students' ability to comprehend text and the change in the students' ability to express their understanding in writing. Each set of data was described citing examples from student work and the reflective journal of the instructor.

Student Perceptions

The initial reaction to the implementation of the literacy strategies was met with mixed responses from the students. Data from the reflective journal showed that the first time students were asked to read and write they were very lethargic about the activity. Students' verbal responses included but were not limited to, "I hate reading," "I am the worst writer," and "I can't do this." Many students simply would not attempt the activity, whether reading or writing. This was clearly shown by a number of students, on average
between five to ten per class, not turning in writing and reading assignments due to lack of completion.

During the course of the study many of these attitudes began to shift, the vast majority towards a more positive view of literacy. There were complaints about the use of writing, but those complaints would likely have accompanied any assignment. Completion of the assignments increased greatly during class, from an average of 75% completion to an average of around 88% completion, and moderately for homework assignments, approximately a 5% increase. When students were asked why homework was incomplete the most common reason was forgetfulness, typically 90% or more, instead of avoidance as seen previously during the study. Some of the negative attitudes during the introduction of the strategies persisted, however many changed to an attitude of acceptance or compliance. Student complaints were greatly reduced and most started the activities with very little hesitation. A select few students actually embraced the idea of reading and writing in science. One particular student asked for an extension on an in class writing assignment so he could do independent research and type his final project. Data suggests that initially 70 of the 96 students demonstrated a positive attitude towards literacy and at the completion of the student 86 of the 96 students showed a positive attitude. Overall there was a more positive attitude towards literacy after completion of the study compared to the beginning.

Reading Comprehension

The baseline reading comprehension work had mixed results. Most students, 90 of 96, were able to comprehend text on a basic factual level and answer the generally straightforward questions that followed. Only about 26 of the 96 student could answer
questions regarded as higher level thinking such as analysis and synthesis questions dealing with the reading. Other reading that followed was more challenging and early on in the study students struggled. Students frequently would read then give up when trying to answer questions relating to the reading.

During the study while students were using the various strategies set forth by the instructor their ability to answer questions thoroughly and correctly increased. Many of the strategies used were new to the students so they were heavily scaffolded during their initial implementation. Subsequent uses of the strategies were much less guided and during their earlier uses some students struggled slightly more with comprehension. At times, students were given the opportunity to read without being instructed to use a particular strategy. There were some students that embraced one strategy or another after its initial implementation and continued to use their chosen strategy on most reading assignments. These students had an increased level of comprehension. This is supported by comments recorded in the instructor's reflective journal and through observations of the student work. Not every student, only between 20% and 25% of the class, benefited from the execution of these different strategies.

Conveying Written Understanding

Early written assessments were very disjointed and student writing was frequently off task. Students struggled to comprehend the writing objectives and to convey their knowledge of the topic in writing. In talking to some of these students it was evident that while they were unable to express their ideas in writing they did comprehend the topic at hand. Some students however could not convey understanding in writing or verbally.
During the course of the study many of the written assignments were graded using variations of the rubric in Appendix D. The various assignments were unable to be compared because most of the writing assignments focused on different specific traits on the rubric. Therefore there was no true way to draw valid conclusions from the grades students received. Fortunately there was information that could be gleaned from the written assessments given to the students. Although different traits from the rubrics were used to assess student work some of the traits remained the same and in most cases student performance remained consistent or increased slightly. The gap between students' verbal expression of understanding and written expression of understanding narrowed. It was also more frequent that if students did not express comprehension in their writing they also did not express comprehension verbally. Some students were not strongly affected by the implementation of these writing strategies. Many students already expressed themselves well in writing and maintained a consistent level of expressed comprehension and others did not show improvement after being introduced to the strategies.

Discussion

Even though the hypothesis was not universally supported by every student’s experience, the data collected from the study supports the initial hypothesis that increased literacy skills will aid in individual student understanding. There was not an overwhelming amount of supporting evidence; however there was no evidence that was found to refute the hypothesis. Most students, 74 of the 96, either showed marginal to moderate improvement or maintained a consistent level in both reading and writing.
It was difficult to collect and analyze the qualitative data dealing with student understanding. Much of these difficulties can be attributed to poor design in the questions being asked. For this reason some doubt can be applied to the data. Additionally, during the course of a school year student achievement should typically increase as students become more comfortable with the style of the teacher and the content of the course. This fact makes it somewhat unclear if other factors were the cause of improved understanding in each of the students.

There is one piece of data that does correlate directly to the increased use of literacy in the classroom, which were the students’ perceptions of reading and writing. Initially, literacy was met by some students with resistance and centered primarily around avoidance or general aversion towards reading and writing. By the end of the study, this had turned at worst to compliance if not enjoyment for some students.

Findings of this study correlated well with previous work done in the field surrounding literacy in education. The use of various strategies, both reading-centered and writing-centered, allowed students the opportunity to grow in their ability to obtain knowledge from text and to express their understanding through writing. Some specific strategies showed striking similarities to research previously conducted. Choe and Drennan (2001) discussed the benefits of jigsaw activities in promoting active learning. When the jigsaw activity seen in Appendix E was used during class, students who were typically passive readers became actively engaged not only in their own understanding of the text but also the understanding of their peers. Lance and Lance (2006) demonstrated the benefits of both using rubrics and short topical essays to aid in student learning and expression of that learning. The results here correspond to the results of Lance and
Lance; these were also two of the most beneficial and embraced strategies by the students in the study. Many of the other previous findings shared common elements and outcomes with the study.

Improvements in literacy skills allowed individual students to increase their amount of success in science, of the 74 who showed improvement 28 of them were grouped as showing substantial growth in literacy and achievement. Overall, even if students were not helped during the course of the study they were at least introduced to many different literacy strategies that they could use or modify for future use. The school's literacy coach mentioned that many of the strategies used in the study were used in other classes, as well as in the senior high school. One of the most beneficial components of this knowledge is the fact that it is entirely transferable. Literacy persists through every academic discipline and life outside of and after school. The implementation of these strategies in the classroom was a worthwhile endeavor for the students and is worth repeating in the future. If repeated it would be in the best interest of the students to begin the strategies at the beginning of the year and continue through the entire course.

The length of time allotted was one of the drawbacks of this study. It was very difficult to observe many significant changes in the ability of the students' reading and writing over the course of only two month. Unfortunately, there was no choice but to have this short amount of data collection time. Even over the course of a single year it may be difficult to observe changes. If the study were to be repeated it would be beneficial to obtain data over the course of at least one full school year if not multiple
years. This may also offer information about which scientific discipline is the most demanding in terms of literacy skills.

The type of data being collected also makes it difficult to firmly support the hypothesis of the study. Methods of data collection could have certainly been improved upon and should be improved upon if repeating this study. More concrete baseline data would create a basis of comparison for individual student growth throughout the study. Common grading practices, such as a consistent rubric, would also be beneficial when repeating this study by supplying quantitative data on achievement to supplement qualitative data. Both of these assessment drawbacks were realized during the course of the study, but too much time had already passed to make them feasible options for change during this specific study.

One last modification which could improve this study in the future would be the addition of a control group. While there was improvement from some students it is difficult to prove a causal relationship with the literacy strategies. Although the sample group was large, it may have proven more beneficial for the results of the study if half of the group was given the assessments with imbedded literacy instruction and the other half given the assessments without imbedded literacy instruction. This would allow the researcher to make a distinction between how a student naturally improves during a class and how literacy guides that improvement.

Despite the drawbacks in experimental design, the study revealed some beneficial information regarding literacy in science. The data shows that literacy can easily be implemented into a dense science curriculum without detracting from instructional topics. It also provides students with additional means of understanding and reporting
information. This creates individuals who can intelligently interpret information found in various media when it is encountered in the future, or as many have termed these individuals, lifelong learners.

Conclusion

This study provided an opportunity to improve student understanding and achievement and also provided an opportunity for the instructor to learn and use valuable teaching strategies. The experience was beneficial for all parties involved. Similar results are not guaranteed; however, this also means that if repeated the results may exceed the expectations of the instructor.

Further research in this area could be done and would increase the knowledge of the subject of literacy in science. One of the easiest ways to extend this study would be to perform the study for an entire school year instead of simply two months. This would allow for different strategies to be used and for students to internalize these strategies much more thoroughly. Another interesting twist may be to focus on reading and writing outside of the classroom in order to promote literacy in a more independent style. Studying this could allow researchers to look at literacy from different perspectives such as motivation to read and write or how student interest drives literacy. Literacy could also be studied across different curricula. Implementing literacy skills for a short period of time during science class had a positive effect on student understanding. Perhaps by focusing on literacy in every class for a group of students, in particular low achieving students, it would be possible to determine if fully integrated literacy impacts student academic performance.
Literacy strategies can be a powerful tool to increase student understanding in the science classroom. Even given the short time frame of the study, there was evidence of improved understanding which correlated with the implementation of literacy strategies during class. At the same time, there was no evidence that the implementation of these strategies hindered the understanding of any students in the study. With careful planning and execution, literacy strategies can be seamlessly integrated into any science classroom giving students the necessary tools to comprehend and express their knowledge in writing.
References


Appendix A: Initial Writing Assessment

You have been assigned to design an experiment to determine the effects of light on the growth of tomato plants. In your experimental design be sure to:

- state one hypothesis to be tested [1]
- identify the independent variable in the experiment [1]
- describe the type of data to be collected [1]

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A team of doctors was sent to Havana, Cuba, to study a yellow fever epidemic. The doctors wanted to find out how the pathogenic microbe that causes yellow fever is transferred from those who are sick to those who are well. Some people thought that the disease was spread by having contact with a person who had the disease or even through contact with clothing or bedding that they had used.

It was known that yellow fever occurred more frequently in swampy environments than in environments that were dry. Consequently, some people thought that the disease was due to contact with the atmosphere of the swamps. A respected doctor in Havana was convinced that a particular species of mosquito, Aedes calopus, spread the disease.

The team of doctors carried out several experiments and collected data. They built poorly ventilated houses in which American soldiers volunteered to sleep on bedding used by individuals who had recently died of yellow fever in local hospitals. The soldiers also wore the nightshirts of those who had died. The houses were fumigated to kill all mosquitoes and the doors and windows of the houses were screened. None of the soldiers living in these houses contracted the disease, though the experiment was tried repeatedly.

In another experiment, the team built houses that were tightly sealed. The doors and windows were screened. The insides of the houses were divided into two parts by mosquito netting. One part of the house contained a species of mosquito, Aedes calopus, that had been allowed to bite yellow fever patients in the hospital. There were no mosquitoes in the other part of the house. A group of volunteers lived in each part of the house. A number of those who lived in the part of the house with the mosquitoes became infected; none of those in the other part of the house did.

Putting these facts together with other evidence, the team concluded that Aedes calopus spread the disease. The validity of this conclusion then had to be tested. All newly reported cases of yellow fever were promptly taken to well-screened hospitals and their houses were fumigated to kill any mosquitoes. The breeding places of the mosquitoes in and around Havana were drained or covered with a film of oil to kill mosquito larvae. Native fish species known to feed on mosquito larvae were introduced into streams and ponds. The number of yellow fever cases steadily declined until Havana was essentially free of the epidemic.

1 State the problem the team of doctors was trying to solve.

2 State one hypothesis from paragraph A that was tested by one of the experiments.

3 Describe the control that should have been set up for the experiment described in paragraph C.

4 Explain why the use of native fish (described in paragraph E), rather than the use of pesticides, is less likely to have a negative impact on the environment.
Appendix C: Creative Writing Assignment

**Write a RAFT about transport across a membrane**

**Role** refers to who you are as the writer.
**Audience** is who you are writing to.
**Format** is what type of writing it is.
**Topic** is what you are writing about.

These are the parts of the assignment given to you; the rest is on your own. Choose one of the three options below and write about it.

<table>
<thead>
<tr>
<th>Option #1</th>
<th>Option #2</th>
<th>Option #3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Role</strong></td>
<td>Cell membrane</td>
<td>Starch molecule</td>
</tr>
<tr>
<td><strong>Audience</strong></td>
<td>New owner</td>
<td>Cell membrane</td>
</tr>
<tr>
<td><strong>Format</strong></td>
<td>Owner’s manual</td>
<td>Petition</td>
</tr>
<tr>
<td><strong>Topic</strong></td>
<td>Explain all of the parts and different functions of the cell membrane, especially transport</td>
<td>Large molecules should be allowed to pass through the membrane like small molecules do</td>
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<td>Trait</td>
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<td>NOT YET</td>
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<td>EMERGING</td>
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<tr>
<td>DEVELOPING</td>
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<tr>
<td>EFFECTIVE</td>
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<tr>
<td>STRONG</td>
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</table>

**Traits**

- **Ideas and Details**
  - Ideas and details are presented in a clear, organized manner.
  - Details are relevant and supported by evidence.
  - Development of ideas is logical and coherent.

- **Organization**
  - Structure and flow of ideas are clear and logical.
  - Transitions between paragraphs or sections are smooth.
  - Main points are clearly stated.

- **Voice**
  - Writing has a rhythm.
  - Specific, precise, and appropriate for audience.
  - Has conviction towards task.

- **Word Choice**
  - Specific, accurate, and varied vocabulary.
  - Appropriate for audience.
  - Logical sequence.

- **Sentence Fluency**
  - Writing has a rhythm.
  - Purposeful sentence beginnings.
  - Writing has a rhythm.

- **Conventions**
  - Correct spelling.
  - Accurate punctuation.
  - Correct grammar.
  - Vary in length and structure.
  - Purposeful sentence beginnings.
  - Writing has a rhythm.
  - Specific, precise, and appropriate for audience.
  - Has conviction towards task.

**Evaluations**

- **STRONG**
  - Usually correct spelling.
  - End punctuation correct, others are not.
  - Problems with grammar.
  - Sentence developed in a routine fashion.
  - Some sentence starters vary.
  - Parts of the writing are fluent while others are choppy.
  - General and adequate for audience.
  - Lacks conviction towards task.
  - Correct and adequate vocabulary.
  - Aware of audience.
  - Sequencing shows some logic.
  - Structure sometimes supports the main point.
  - The reader is left with questions.

- **EFFECTIVE**
  - Usually correct spelling.
  - Accurate punctuation.
  - Correct grammar.
  - Vary in length and structure.
  - Purposeful sentence beginnings.
  - Writing has a rhythm.
  - Specific, precise, and appropriate for audience.
  - Has conviction towards task.
  - Specific, adequate and varied vocabulary.
  - Appropriate for audience.
  - Logical sequence.
  - Structure sometimes supports the main point.
  - Narrow and manageable topic.
  - Insight into picking out what is significant.

- **DEVELOPING**
  - Frequent spelling errors.
  - Missing punctuation.
  - Errors in grammar.
  - Inadequate vocabulary.
  - Inadequate for audience.
  - No clear purpose.
  - Writing lacks logic.
  - Lacks connection.
  - Writing is unclear.
  - No clear purpose for audience.
  - No connection to audience.
  - Broad topic, but headed in the right direction.
  - Has difficulty going from general observations to specifics.
  - The reader is left with questions.

- **EMERGING**
  - Frequent spelling errors.
  - Missing punctuation.
  - Errors in grammar.
  - Inadequate vocabulary.
  - Inadequate for audience.
  - No clear purpose.
  - Writing lacks logic.
  - Lacks connection.
  - Writing is unclear.
  - No clear purpose for audience.
  - No connection to audience.
  - Broad topic, but headed in the right direction.
  - Has difficulty going from general observations to specifics.
  - The reader is left with questions.

- **NOT YET**
  - Frequent spelling errors.
  - Missing punctuation.
  - Errors in grammar.
  - Inadequate vocabulary.
  - Inadequate for audience.
  - No clear purpose.
  - Writing lacks logic.
  - Lacks connection.
  - Writing is unclear.
  - No clear purpose for audience.
  - No connection to audience.
  - Broad topic, but headed in the right direction.
  - Has difficulty going from general observations to specifics.
  - The reader is left with questions.
Appendix E: Textbook Jigsaw Activity

<table>
<thead>
<tr>
<th>Pages 291 – 292</th>
<th>Pages 292 -294</th>
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<tbody>
<tr>
<td><strong>Headings</strong></td>
<td><strong>Headings</strong></td>
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<tr>
<td>The Structure of DNA</td>
<td>X-Ray Evidence</td>
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<tr>
<td>Chragaff’s Rules</td>
<td>The Double Helix</td>
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<tbody>
<tr>
<td><strong>Headings</strong></td>
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<tr>
<td>DNA and Chromosomes</td>
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<tr>
<td>DNA Length</td>
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<tr>
<td>Chromosome Structure</td>
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DNA Jigsaw
Each member of the group will be responsible for giving the group certain information. You will split into your specialty groups then read and discuss your section with your specialty group. Once you have finished you will return and report back to your original group. Each group member will be responsible for teaching a section of the text to the rest of the group.

**Section 1: The Structure of DNA**

Important facts

Vocabulary words

Connections to content/personal experience

**Section 2: The Double Helix**

Important facts

Vocabulary words

Connections to content/personal experience
Section 3: DNA and Chromosomes

Important facts

Vocabulary words

Connections to content/personal experience
Appendix F: High Interest Reading Guide

Teen’s Story is Tall Tale

Pre-reading
Write whether you agree or disagree with each statement

□ Being tall is a good thing.
□ I would want a gene that could make me taller if it was possible.
□ Mutations are always a bad thing.
□ I wish I was bigger than the adults I know.
□ Doctors can find a medicine to help solve every condition

During reading
What condition effected Brenden? Which chromosome? Which gene?

What type of mutation was this?

What are some of the effects of this mutation?

What are some of the treatments used to handle the condition?

Below is a karyotype, a visual list of all the chromosomes in an organism. It allows scientists and doctors to view a person’s set of chromosomes to check for abnormalities that might cause certain medical conditions. Circle the specific chromosome responsible for Brenden’s condition.

Follow up
The article on the next two pages was written about a year after the article you just read. It follows up on Brenden and how he is handling his condition.
Appendix G: Final Writing Assessment

Scientists have successfully cloned sheep and cattle for several years. A farmer is considering the advantages and disadvantages of having a flock of sheep cloned from a single individual. Discuss the issues the farmer should take into account before making a decision. Your response should include:

- how a cloned flock would be different from a non-cloned flock [1]
- one advantage of having a cloned flock [1]
- one disadvantage of having a cloned flock [1]
- one reason that the farmer could not mate these cloned sheep with each other to increase the size of his flock [1]
- one reason that the offspring resulting from breeding these sheep with an unrelated sheep would not all be the same [1]