

Improving Reading Comprehension Skills in High School Biology Curricula

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Overview

Personal observations as a high school science teacher spanning a twenty-seven year career with the School District of Philadelphia has led to the conclusion that academic achievement in the sciences, whether that be in the life sciences or the physical sciences, is directly related to a student's ability to read and comprehend grade level informational text. With that in mind, this curriculum unit will examine current literature regarding the state of science literacy at the secondary level, in addition to, various pedagogical strategies and resources that can be used in a traditional high school biology classroom. The main goal of this unit is to incorporate a variety of teaching strategies throughout the year that will ultimately improve the reading comprehension skills in various high school biology courses. It is intended to address two distinct groups of students. The first group includes ninth grade students who are taking the School District of Philadelphia's standardized curriculum for biology. The second group includes those students enrolled in the standard level International Baccalaureate (IB) biology course and who are in the eleventh or twelve grades.

Rationale

Background Information on Science Literacy

High school students enrolled in the School District of Philadelphia generally score below grade level on standardized tests in reading and science. Most of the reading deficiencies are related to nonfiction, informational text. This curriculum unit was designed to address strategies to improve reading comprehension among students in high

school biology classes. The rationale section of this curriculum unit is divided into two sections. The first portion will concentrate on identifying those objectives and/or goals associated with understanding the science content at the secondary level, whereas the second portion will focus on developing strategies for improving science literacy.

Major concerns regarding the quality of education in the United States date back at least thirty years. The U. S. Secretary of Education in 1981, T. H. Bell, established the National Commission on Excellence in Education arising from public concern regarding the state of education in the United States. The commission which was composed of eighteen members published their findings less than two years later in a report entitled “A Nation at Risk: The Imperative for Educational Reform”. That report delineated numerous deficiencies, shortcomings and concerns with regard to the educational system in the United States. The commission was able to classify the concerns into “four main aspects of the educational process” which included: content, expectations, time, and teaching. There are two principal points of interest from that report that are relevant to this unit. The first concern deals with content and the decrease in the number of higher level courses offered at the secondary level. The second concern deals with the declining results on standardized tests (1).

In 1989, the American Association for the Advancement of Science (AAAS) proposed a long range educational initiative entitled Project 2061. The project involved three distinct phases. In their first publication on the project, *Science for All Americans (SFAA)*, the three phases are described in detail (2). Phase I of the project “attempted to establish a conceptual base for reform by defining the knowledge, skills, and attitudes that all students should acquire as a consequence of their total school experience, from kindergarten through high school”. As for Phase II, “The main purpose of the second phase of the Project is to produce a variety of curriculum models that school districts and states can use as they undertake to reform the teaching of science mathematics and technology”. With regard to Phase III, “...the Project will collaborate with scientific societies, educational organizations and institutions, and other groups involved in the reform of science, mathematics, and technology education in a nationwide effort to turn the Phase II blueprints into educational practice”. The primary goal of Project 2061 was to make all Americans literate in science by the year 2061. To achieve that goal the project was based on the following five basic principles:

1. “All children need a basic education in science, mathematics, and technology that prepares them to live interesting and productive lives.”
2. “World norms for what constitutes a basic education have changed radically in response to the rapid growth of scientific knowledge and technological power.”
3. “U.S schools have yet to act decisively enough in preparing young people – especially minority children, on whom the future of America is coming to depend – for a world shaped by science and technology.”

4. "Sweeping changes in the entire educational system from kindergarten through twelfth grade will have to be made if the United States is to become a nation of scientifically literate citizens."
5. "A necessary first step in achieving systematic reform in science, mathematics, and technology education is reaching a clear understanding what constitutes science literacy."

Four years after the publication of *SFAA*, a companion book entitled *Benchmarks for Science Literacy* was published. In that report, it was stated "*Benchmarks* specifies how students should progress toward science literacy, recommending what they should know and be able to do by the time they reach certain grade levels" (3). The three visions for Project 2061 in the twenty-first century were stated as follows (4):

1. "First, an identifiable *common core* of learning in science, mathematics, and technology will focus on science literacy as its main goal and be closely allied with a common core of learning in the arts and humanities."
2. "Second, all students in a Project 2061 school will have wide-ranging learning experiences."
3. "Third, teachers will have primary responsibility for planning and implementing curriculum within their individual systems."

Over the years, the term "science literacy" has taken on various connotations. In an article written by Xiufeng Liu, the author discusses those differences from the late 1950's until the early part of the twenty-first century. As stated in the article, "I agree with James Rutherford, director of Project 2061 at AAAS, that science literacy should refer to *literacy with regard to science*, while scientific literacy refers to *scientific nature of literacy* in all forms such as science, English language, technology, and so on (Roberts, 2007)." Xiufeng further clarifies the two by stating that the former, science literacy, should be related to "goals of science education" whereas the latter is "related to approaches to achieving science literacy. He goes on to reiterate the 2007 position of National Research Council on the need for literacy in science by including the following quote:

"Specifically, school science education should promote scientific proficiency because:

1. Science is a significant part of human culture and represents one of the principles of human thinking capacity;
2. It provides a laboratory of common experience for development of language, logic and problem-solving skills in the classroom;
3. A democracy demands that its citizens make personal and community decisions about issues in which scientific information plays a fundamental role, and they hence need a knowledge of science as well as an understanding of scientific methodology;

4. For some students, it will become a lifelong vocation or avocation; and
5. The nation is dependent on the technical and scientific abilities of its citizens for its economic competitiveness and natural needs. (NRC, 2007, p34)” (5)

Whereas the need for educational reform in the United States is unquestioned, the learning goals and/or objectives from kindergarten through grade twelve remain quite vague. According to *SFAA*, “One fundamental premise of Project 2061 is that schools do not need to be asked to teach more and more content, but rather to focus on what is essential to science literacy and to teach it more effectively.” (6) Additionally, *SFAA* is structured around this statement “*Science for All Americans* is based on the belief that the science-literate person is one who is aware that science, mathematics, and technology are interdependent human enterprises with strengths and limitations; understands key concepts and principles of science; is familiar with the natural world and recognizes both its diversity and unity; and uses scientific knowledge and scientific ways of thinking for individual and social purposes.” (7)

The National Research Council (NRC) established the National Science Education Standards in 1996. The content standards for grades nine through twelve are given in detail but include the following categories: “Unifying Concepts and Processes, Science as Inquiry, Physical Science, Life Science, Earth and Space Science, Science and Technology, Science in Personal and Social Perspectives, and History and Nature of Science”. (8) The NRC went on to propose that teachers put more emphasis on the following (9):

1. “Understanding and responding to individual student’s interests, strengths, experiences and needs.”
2. “Selecting and adapting curriculum.”
3. “Focusing on student understanding and use of scientific knowledge, ideas, and inquiry processes.”
4. “Guiding students in active and extended scientific inquiry.”
5. “Providing opportunities for scientific discussion and debate among students.”
6. “Continuously assessing student understanding.”
7. “Sharing responsibility for learning with students.”
8. “Supporting a classroom community with cooperation, shared responsibility, and respect.”
9. “Working with other teachers to enhance the science program.”

In an article entitled “Science Literacy for All in the 21st Century”, the author George D. Nelson reported that the AAAS, National Academy of Sciences, and the National Science Teachers Association released the following joint statement regarding science literacy in 1996 (10):

- “The first priority of science education is basic science literacy for all students, including those in groups that have traditionally been poorly served by science education.”
- “Education for universal science literacy will, in addition to enriching everyone’s life, create a larger and more diverse pool of students who are able and motivated to pursue further education in scientific fields.”
- “Science literacy consists of a knowledge of certain important facts, concepts, and theories; the exercise of scientific habits of mind; and an understanding of the nature of science, its connections to mathematics and technology, its impact on individuals, and its role in society.”
- “For students to have the time needed to acquire the essential knowledge and skills of science literacy, the sheer amount of material that today’s science curriculum tries to cover must be significantly reduced.”
- “Effective education for science literacy requires that every student be frequently and actively involved in exploring nature in ways that resemble how scientists work.”

Strategies for Improving Reading Comprehension

After a review of the literature, three common principles become apparent regarding improving science literacy and they include: actively engaging students in experiential learning, reducing the amount of content material, and allowing students to debate relevant issues. Using the aforementioned as guiding principles to improving science literacy, the next section of this unit will concentrate on activities that include one or all three of them. The very first standard of the NRC’s National Science Education Standards states “Teachers of science plan an inquiry-based science program for their students.” (11) Features within classrooms conducting inquiry-based learning are outlined in *Inquiry and the National Science Education Standards* (12) and include the following:

1. “Learner engages in scientifically oriented questions.”
2. “Learner gives priority to evidence in responding to questions.”
3. “Learner formulates explanations from evidence.”
4. “Learner connects explanations to scientific knowledge.”
5. “Learner communicates and justifies explanations.”

Although the need for improving science literacy among students from kindergarten through twelfth grade is universally accepted, the means for achieving it are far less clear. Whether the pedagogical strategies include inquiry-based learning, project-based learning, problem-based learning or the involvement of information communication and technology (ICT), reading and writing appear to be common to any strategy involving literacy. In an article published in 2002, Jonathan Osborne supports the idea that in order

for students to be literate in science they must read scientific material, discuss the merits of the scientific information and be able to use scientific terminology in writing (13). Heselden and Staples reported also in 2002 that for students to learn science departments need to become active in addressing reading skills. In addition to listing pedagogical strategies that aid in improving the reading skills of students, the authors make a clear distinction between passive and active reading. Even though they mention acceptable methods for using passive reading, the authors encourage the use of active reading strategies. One such strategy known as DARTs is the acronym for Directed Activities Related to Text. They go on to outline in detail four such DART activities. The authors conclude that teachers must first determine the purpose of the lesson before assigning a reading activity along with the appropriate reading material (14).

In response to the conclusion of a 2004 report which indicated that high school graduates are inadequately prepared to succeed in society, the National Governors Association and the Council of Chief State School Officers set out to establish national curriculum standards for literacy and mathematics. Since its publication in 2010, the Common Core State Standards have been adopted by forty-five states (15). The college and career readiness anchor standards for reading include: key ideas and details, craft and structure, integration of knowledge and ideas, and range of reading and level of text complexity. Within each of the anchor standard are common core standards which students should be able to achieve within each grade level. For example, students in grades nine and ten should be able to: “Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.” (16). The term “technical texts” includes the use of primary sources of information as well as the traditional secondary sources which most science classes utilize. It is interesting to note that in 2001 the article “Primary literature as a basis for a high-school biology curriculum” was published. In that article, the authors point out that at the collegiate level primary sources of literature are the basis for many courses. With that in mind, they examined the possibility of using primary sources such as research articles to teach a high school developmental biology course. The course was designed for biology majors in grades eleven and twelve. Although they concede to the difficulties in teaching with primary research articles, the authors state “Choosing appropriate research articles, processing those articles, and reading them in a way that enables the students to interact with them, are all means of facilitating high-school students’ understanding of the content of research articles.” (17)

The Office of Curriculum, Instruction, and Assessment of the School District of Philadelphia has recently prepared a resource booklet for teachers that outlines strategies that support the goals of the common core standards (18). It mentions three specific areas that are partially responsible for the decline of reading comprehension among U.S. students which include: the emphasis on narrative as compared to expository text in grades K-12, poor scaffolding strategies, and personal impressions rather than textual connections (19). With regard to literacy, the emphasis is on instructional reform. More

specifically, one of the instructional reforms requires the use of nonfiction, informational text in grades K-12 in order to improve content based knowledge. To achieve this goal, the School District of Philadelphia is encouraging the use of a strategy called “Close Reading”. The seven major student aims of this critical analysis strategy are (20):

- “understanding your purpose in reading:
- “understanding the author’s purpose in writing”
- “seeing ideas in a text as being interconnected”
- “looking for and understanding systems of meaning (understanding and making logical connections among ideas; monitoring while I read)”
- “engaging a text while reading”
- “getting beyond impressionist reading (requires reading with a critical eye”
- “formulating questions and seeking answers to those questions while reading”

A guide is presented to help teachers prepare critical thinking questions that could help students in reading and comprehending informational text. The outline focuses on the following seven steps:

1. “Identify the Core Understandings and Key Ideas of the Text”
2. “Start Small to Build Confidence”
3. “Target Vocabulary and Text Structure”
4. “Tackle Tough Sections Head-on”
5. “Create Coherent Sequences of Text Dependent Questions”
6. “Identify the Standards That Are Being Addressed”
7. “Create the Culminating Assessment”

The booklet also contains an article written by Elfrieda H. Hiebert in which the author clearly outlines seven actions that teachers can take in addressing the Common Core State Standard involving the complexity of curriculum text. Those actions include the following (21):

1. “Focus on Knowledge”
2. “Create Connections”
3. “Activate Students’ Passion”
4. “Develop Vocabulary”
5. “Increase the Volume”
6. “Build Up Stamina”
7. “Identify Benchmarks”

This resource booklet, which also contains a number of useful graphic organizers, will be an extremely beneficial tool in improving reading comprehension the classroom (22).

Objectives

The primary behavioral objective of this unit is to improve the reading comprehension skills in various high school biology courses. It is designed to be a year long, ongoing project that will incorporate a variety of pedagogical resources and strategies. It is envisioned that these resources and/or strategies will not only aid in improving student reading abilities, but they will also help to foster understanding of content specific concepts. The standards and concepts presented in this curriculum unit are in direct alignment with both the Pennsylvania Academic Standards for Science and Technology and the School District of Philadelphia's standardized curriculum for biology.

As designed, this curriculum unit will target a number of Pennsylvania Academic Standards for Science and Technology. They include, but are not limited to, the following standards: 3.1.10 "Unifying Themes", 3.2.10 "Inquiry and Design", 3.3.10 "Biological Sciences", 3.7.10 "Technological Devices", and 3.8.10 "Science, Technology, and Human Endeavors". The specific standards are outlined in the appendix section of this unit.

Strategies

In an ongoing effort to improve student literacy, the School District of Philadelphia adopted an initiative based on six instructional strategies (23). Among the strategies that will be used throughout this unit are: previewing content specific vocabulary, summarizing material by structured note taking, reciprocal teaching, and writing short compositions on what has been read.

Parts of the unit will also necessitate the use of cooperative learning strategies. Classroom management, however, is essential for a successful cooperative learning environment. This can be accomplished through: cooperative management, the will to cooperate, and the skill to cooperate. It is imperative that students understand the guidelines for acceptable classroom behavior. The will to cooperate is developed over time and is based on positive social interactions and pride within the group. The skill to cooperate is based on the ability of the students to assume specific roles within the group, listen to, and work with each other.

The fundamental behavioral skills that are associated with cooperative learning include: simultaneous interaction, positive interdependence, and individual accountability. Within a cooperative learning environment, the students are encouraged to interact with members within their group. This freedom is usually not permissible within a traditional classroom setting. Positive interdependence is gained from the achievement of individual students

within the group and from the entire group as a whole. Individual accountability can be addressed by employing a variety of assessments.

Classroom management is always a major concern especially with freshman students. To a large degree, effective classroom management depends upon the structure of the lesson and its delivery. Not only does it involve the arrangement of the students within the group, but it is also dependent upon the manner in which individual lessons are designed and presented. These structures, designs, or activities are meant to improve such areas as team building, information sharing, thinking skills, communication skills, and content literacy. A brief list of classroom structures and lesson designs include: brainstorming, jigsaw, numbered heads together, rally table, round robin, roundtable, student teams achievement division (STAD), team projects, and think pair share. A detailed review of each can be found in *Cooperative Learning* (24).

By improving their note taking skills, students should be able to utilize, practice and/or engage in summarizing content specific material. To achieve that objective, the highly successful technique of note taking that was developed by Walter Pauk will be employed. The Cornell Method, as it is referred to, involves writing a key word, phrase, or concept on the left hand side of a sheet of paper. On the right hand side of the paper, relevant material is then written in short sentences or phrases. Finally, at the bottom of the page, the material listed is then summarized into a short paragraph. This widely used method enables students to improve their skills in summarizing material presented in both lecture and written form (25).

In order to address and improve reading comprehension skills, students will participate in reciprocal teaching techniques. This is another cooperative learning strategy which is designed to encompass the following four skills: summarizing, questioning, clarifying, and predicting. Each student within the group will be responsible for reading a specific section within their textbook and/or assigned reading material, summarizing that material, and reporting out to the rest of the group. This pedagogical strategy has been reported to be successful in both small groups as well as in large classroom settings (26).

Classroom Activities

Activity 1:

As part of the yearlong project, students will be expected to keep a current events journal. Once a week, the students will be given an article from the online science news magazine, *Science Daily*, obtained from <http://www.sciencedaily.com>. Along with a template for the Cornell Method, each student will be expected to outline the article and write a brief summary. It is anticipated that this ongoing activity will not only improve the students' reading comprehension, but it will also improve their science literacy.

Activity 2:

Unit 3 of the School District of Philadelphia's Standardized Curriculum for Biology is entitled "Cell Structure and Function". Part of the unit is devoted to the transport of molecules across cell membranes. Behavioral objectives for this unit include being able to compare and contrast the processes of osmosis and diffusion, determine the direction of flow into or out of the cell on the basis of concentration gradients, and understand the effect of cells when placed in hypo-, hyper-, and isotonic solutions. Activity 1 is aimed at improving students' ability to read and comprehend scientific concepts when given a real world situation. Part 1 of the activity deals with a farmer's son who puts too much potash and phosphate on a corn field. In Part 2, a patient with a gunshot wound was mistakenly given distilled water intravenously instead of saline solution.

This activity, therefore, will coincide with the section on osmosis. It involves a case study entitled "Osmosis is Serious Business" which was obtained from the National Center for Case Study Teaching in Science (27). It is a two part activity involving hypertonic and hypotonic cell environments. Students will be directed to work in small groups. After reading each case study, the students will evaluate the relevant data in order to answer the accompanying questions.

Activity 3:

The pedagogical use of science fiction in the classroom is not a new idea. Over twenty years ago, Leroy W. Dubeck *et.al.* published an article entitled "Science Fiction Aids Science Teaching". They reported that teachers from twenty-two high schools and two junior high schools introduced science fiction films into their classrooms with positive results in "attitudes toward science, knowledge of science as a discovery process, and cognitive development" (28). The world renowned astrophysicist, Stephen Hawking, also has provided support for the inclusion of science fiction in the classroom. In the forward to The Physics of Star Trek, Professor Hawking stated "Science fiction like Star Trek is not only good fun but it also serves a serious purpose, that of expanding the human imagination...Science fiction suggests ideas that scientists incorporate into their theories, but sometimes science turns up notions that are stronger than any science fiction...Nevertheless, today's science fiction is often tomorrow's fact" (29).

This activity is intended to be the culminating activity to Unit 4 of the School District of Philadelphia's Standardized Curriculum for Biology entitled "Cellular Respiration and Photosynthesis". By the end of this unit, the students should be able to: understand the structure of ATP, compare and contrast the processes of photosynthesis and cellular respiration, and explain the flow of energy through living organisms. In this activity, the students will be arranged into cooperative learning groups of four. Each group will read a short portion of Lord Byron's poem "Darkness" (30). Individual groups will then summarize to the entire class what they have read. The students will then individually

write a one page composition dealing with life on Earth without energy from the Sun. In their composition they must include the following:

1. Explain the overall process of photosynthesis.
2. Explain the role of energy from the sun in the first stage of photosynthesis.
3. Summarize the effects of diminished photosynthesis on biological systems.

Activity 4:

Unit 7 of the School District of Philadelphia's standardized curriculum for biology is entitled "Molecular Basis of Inheritance". This activity is aligned with Pennsylvania State standards 3.1.10. E, 3.3.10.B, 3.3.10.C, 3.3.10.C, and 3.6.10.A. This will be the culminating activity for Unit 7 and will involve problem-based learning. In a 2007, Hmelo-Silver et. al. discussed scaffolding as a means of improving student cognition when using problem-based and/or inquiry learning (31). The three specific scaffolding strategies that were mentioned include: the use of well designed questions that support critical thinking skills, the use of evidence provided by an expert and the use of a visible outline for completing the project. These techniques will be extremely useful in guiding the students through this activity.

Implementation of this activity will require placing the students into collaborative groups of four and presenting them with the following problem-based learning scenario:

You are a member of a research team working for a major international pharmaceutical company. Your team is made up of an endocrinologist, a pharmaceutical chemist, a pharmacologist, and a molecular biologist. The team's assignment is to develop a new drug for the treatment of type I diabetes. As part of the developmental process, the team needs to address the following questions: 1. how does type I diabetes differ from type II diabetes, 2. using the most current advances in nanotechnology, what drug delivery system will be used and how will it specifically target those cells producing insulin, 3. what is the mechanism by which the drug will be transported across the cell membrane, 4. once the drug is in the cell, how will it act in stimulating the production of insulin, and 5. what are the ethical considerations in the manufacturing and/or disposal of the drug? The team is required to create a ten minute power point to be presented to the company's director of research and development.

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The Close Reading strategy is outlined in detail.

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Appendix/Standards

This curriculum unit will be aligned to the Pennsylvania academic standards for science and technology and the School District of Philadelphia's Standardized Curriculum for Biology. The specific standards that will be addressed during the course of this curriculum unit were taken directly from the Pennsylvania Teacher's Desk Reference and Critical Thinking Guide and include:

3.1.10 Unifying Themes:

- B. Describe concepts of models as a way to predict and understand science and technology.
 - Apply mathematical models to science and technology.
- D. Apply scale as a way of relating concepts and ideas to one another by some measure.
 - Apply dimensional analysis and scale as a ratio.
 - Convert one scale to another.
- E. Describe patterns of change in nature, physical and manmade systems.
 - Describe the effects of error in measurements.

3.2.10 Inquiry and Design:

- B. Apply process knowledge and organize scientific and technological phenomena in varied ways.
 - Describe materials using precise quantitative and qualitative skills based on observations.
 - Develop appropriate scientific experiments.
 - Use process skills to make inferences and predictions.
- C. Apply the elements of scientific inquiry to solve problems.
 - Organize experimental information using a variety of analytical

- methods.
 - Judge the significance of experimental information in answering the question.
 - Suggest additional steps that might be done experimentally.
- D. Identify and apply the technological design process to solve problems.
- Propose and analyze a solution.
 - Evaluate the solution, test, redesign and improve as necessary.
 - Communicate the process and evaluate and present the impacts of the solution.

3.3.10 Biological Sciences:

- A. Explain the structural and functional similarities and differences found among living things.
- Explain the relationship between structure and function at the molecular and cellular levels.
- B. Describe and explain the chemical and structural basis of living organisms.
- Describe the relationship between the structure of organic molecules and the function they serve in living organisms.
 - Explain cell functions and processes in terms of chemical reactions and energy changes.
- C. Describe how genetic information is inherited and expressed.
- Compare and contrast the function of mitosis and meiosis.
 - Distinguish different reproductive patterns in living things.
 - Explain the relationship among DNA, genes and chromosomes.
 - Describe the role of DNA in protein synthesis as it relates to gene expression.

3.6.10 Technology Education:

- A. Apply biotechnologies that relate to propagating, growing, maintaining, adapting, treating and converting.
- Apply knowledge of biomedical technology applications in designing a solution to a simple medical problem.

3.7.10 Technological Devices:

- B. Apply appropriate instruments and apparatus to examine a variety of objects and processes.
- Describe and use appropriate instruments to gather and analyze data.
 - Compare and contrast different scientific measurement systems.
 - Explain the need to estimate measurements.
 - Apply accurate measurement knowledge to solve everyday problems.
- C. Apply basic computer operations and concepts.
- Analyze and solve basic operating systems problems.

D. Utilize computer software to solve specific problems.

- Apply advanced graphic manipulation and desktop publishing techniques.
- Apply basic multimedia applications.
- Apply advanced word processing, database and spreadsheet skills.

3.8.10 Science, Technology and Human Endeavors

A. Analyze the relationship between societal demands and scientific and technological enterprises.

- Identify past and current tradeoffs between increased production, environmental harm and social issues.
- Describe and evaluate social change as a result of technological developments.