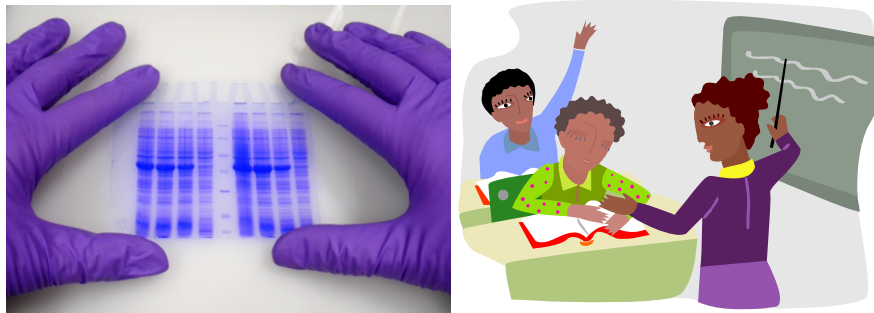A Study of Inquiry Investigations Using Biotechnology in Anatomy and Physiology
Secondary Education to Improve Attitudes towards Science

Action Research Proposal

Valerie R. Pfister, Ph.D.
Teacher, Santa Fe High School
Alachua County School District
11th and 12th Grades
Anatomy and Physiology
September 8, 2010

A Study of Inquiry Investigations Using Biotechnology in Anatomy and Physiology
Secondary Education to Improve Attitudes about Science

Abstract

This action research project will compare the attitudes toward science of high school Anatomy and Physiology students receiving a curriculum of biotechnology inquiry-based activities to those of similar students receiving a more traditional curriculum. The inquiry activities will be integrated over a period of 4 weeks of curriculum that covers cell basics and the lymphatic system. Students' attitudes will be measured prior to the study of the lessons and then immediately following the study units. Observations regarding the students' interest and activity completion will be collected and recorded daily during the curriculum study along with the survey data in order to determine any changes in attitude toward science that may result from the inquiry lessons.

Introduction

The main focus of this action research project is based upon two observations made in the classroom. First, a majority of the students enrolled in Anatomy and Physiology signed up for the class for the sole reason of fulfilling the graduation requirement of three science credits. Second, interest in the focus of the lessons seemed to increase when the students were asked to participate in an inquiry activity related to the lesson. However, no measurements of this perceived increase were ever made. Students who have a genuine increase in interest in any aspect of the Anatomy and Physiology lessons will learn more about the topics, as they engage intellectually. This research will attempt to determine any changes in attitude toward science both quantitatively and qualitatively.

Context

During the 2009 – 2010 school year, four classes of Anatomy and Physiology were offered to students as an alternative to fulfill their third credit of science needed to graduate. Students took the class to fulfill this requirement and to avoid taking the alternative science class, chemistry. When questioned about their interest in learning Anatomy and Physiology, the vast majority of these students had little interest in this or any other science and only took the class due to the graduation requirement. This action research project will concentrate on these students, who are primarily 11th and 12th graders.

Rationale

Students' attitudes toward science have been a concern for the past two decades as indicators point to declining interest from students and an increase in scientific ignorance within the general population (Osborne, 2003). As children age, attitudes towards science decline (Yager and Penick, 1986). Fewer students are choosing science careers at the same time that society has become increasingly dependent upon general science knowledge and our culture has increased its

technological dependence (Osborne, 2003). This decline is of concern because the skills of functional scientific literacy are essential components of conscientious citizenship (Walczak, 2009). Scientific literacy refers to the familiarity with science on the part of the general public (DeBoer, 2000). Students who are not science majors need to understand the science vocabulary to be able to read and write nontechnical science in today's increasingly science- and technology-rich society (Walczak, 2009).

Given the concerns over the need for a basic science literacy and factors that contribute to positive attitudes, Ong and Ruthven (2009) measured attitudes towards science in 775 Malaysian high school students. Differences in attitudes were noted based upon the type of schools attended: Mainstream versus Smart Schools. Students from the Smart Schools had a significantly higher level of attitudes toward science than did students from Mainstream Schools. The major difference in the teaching-learning practices between the Smart School and Mainstream School is that the Smart School is the emphasis on information technology, critical thinking, and productivity. The Smart School curriculum is drawn from best practices around the world and encompasses content knowledge, problem solving knowledge, epistemic knowledge, and inquiry knowledge. The Smart School pedagogy is primarily student-centered and self-directed, where the teachers' roles are primarily to guide the students (Ong and Ruthven, 2009).

Another recent study conducted by Walczak (2009) also found that when real-world components were incorporated into a chemistry course and laboratory experiences, the students were more involved, and had greater confidence about reasoning. These factors increased metacognitive awareness and improved mastery of general concept knowledge when compared to traditional lecture/laboratory classes. Students that participated in cooperative learning activities were more likely to have a greater perception of relevance of chemistry in their lives and thus had more positive attitudes toward learning chemistry (Walczak, 2009).

In addition to real-world experiences, inquiry-based science lessons have proven to improve attitudes toward science (Gibson and Chase, 2002). Pretest and posttest scores of attitudes towards science were measured in students who attended a two-week inquiry-based science camp versus students who other students interested in science but had not attended the camp. Results indicate that students participating in the two-week inquiry-based camp maintained a more positive attitude toward science than students interested in science who did not attend the camp (Gibson and Chase, 2002).

Along with real-world experiences and inquiry-based science lessons, computer-based science instruction seems to promote favorable attitudes towards science as well (Kulik and Kulik, 2003). Thus, with the waning attitudes toward science in high school students, a slight alteration of the delivery of the science curriculum through the incorporation of one or more of the strategies described above would likely have a positive impact on attitudes toward science and consequently, improved attitudes may improve interest and thus comprehension of the science concepts.

Based upon these ideas, Biotechnology is an emerging field of science that will likely play a larger role in the understanding of genetic anomalies and disease processes. Although Biotechnology is a very old field including processes that include the technique for making bread or wine, since the early 1980's, the science has exploded with genetic engineering and investigations into the causes and cures for many diseases (Harms, 2002). Thus, today's science student needs the basic knowledge of this discipline of science to be able to make informed decisions regarding the risks versus the potential benefits of this type of research. Students should learn about microorganisms and their central role in the biotechnology techniques. In addition, the complex issues of biotechnology are best addressed in an interdisciplinary format. Student interest in and attitudes toward biotechnology develop around age 16. Girls tend to be more interested in the social and ethical aspects, while boys tend to be more focused on the economical and technical aspects. Regardless of the focus, having any interest tends to have a positive effect on learning outcomes (Harms, 2002).

Action Research Intervention

Given the documented importance of science literacy, the initial proven success of inquiry-based science education, and the burgeoning field of Biotechnology, the focus of this action research will use Biotechnology activities for inquiry investigations in Anatomy and Physiology to determine any changes in attitudes towards science. The Anatomy and Physiology class includes 11th and 12th graders in a rural high school in Florida.

The basics of the planned action research intervention include an experimental design which includes the following:

1. Prior to the initiation of the action research intervention, a survey (Moore and Foy, 1997) (Appendix 1) on attitudes toward science will be given to all enrolled students.
2. Over a period of 3 weeks, three classes of approximately 25 students in each will receive an inquiry-based science curriculum (sample lesson plan is provided in Appendix 2) on topics that cover cell structure, DNA and the immune system. The inquiry activities will focus on biotechnology concepts and techniques and include the instruction of pipetting, gel electrophoresis to study DNA and its uses in forensics, and finally the application of ELISA tests that can indicate immunologic activity in the human body and its detection.
3. Over the same 3 weeks, three classes of approximately 25 students in each will receive a more traditional delivery of the same curriculum, which includes lectures with note-taking, followed by review activities.
4. The equivalency of the experimental and control classes will be determined using the pre-survey of attitudes toward science as well as class averages of the lessons held during the first two months of school. The pre-survey will be scored to determine an overall average attitude toward science for each class. Classes will be divided into the control and experimental groups so that both the control and experimental groups have students with similar average achievement in Anatomy and Physiology as well as attitudes toward

science. Throughout the 3-week period, a teacher's journal will be maintained to record anecdotal observations on the students' attentiveness, participation levels, and perceived interest in the topic. The number of behavior-correction interventions for each class will be documented as well.

5. Following the completion of the curriculum, all students enrolled will re-take the survey on attitudes toward science.
6. The data collected pre and post intervention will be evaluated to determine any changes in attitude toward science. The results from the inquiry-based intervention classes will be compared with those from the classes receiving the more traditional delivery of the curriculum. The anecdotal observations will also be summarized and supplement the survey findings.
7. Given the experimental design, the data collected will lend itself to a comparative analysis of achievement (measured through traditional testing of concepts presented) between the control and experimental groups. This analysis may then be correlated with the attitude data.

Connections to Bench to Bedside Summer Institute

The ideas for the inquiry-based activities designed for this study were based upon the biotechnology concepts learned during the two-week Bench to Bedside Summer Institute. The materials to be used in the inquiry-based activity lessons will be provided by the Bench to Bedside resources.

Data Collection and Analysis

Both qualitative and quantitative data will be collected during this study. The qualitative data includes the daily recording of comments in a teacher's journal. The comments will reflect the students' attentiveness, participation levels, and perceived interest in the topic. The journal will also reflect an estimate of the number of behavior-correction interventions for each class. This data will be read, described and categorized on a daily basis in an attempt to group the data into related threads or themes.

The quantitative data collected through the students' participation in a pre and post survey of their attitudes toward science will be summarized and analyzed statistically. Descriptive statistics will be used to assign point values to survey responses in order to determine measures of central tendency along with a measure of the variability in responses between the variable and control groups regarding attitudes toward science from the beginning of the study to the end of the study. Statistical analyses will determine if there is any significant change in attitudes toward science between the control and variable groups of students participating in the study.

Finally the scores achieved by the control groups and experimental group from traditional testing over the material, concepts and techniques learned will be compared and correlated with the pre and post-attitude surveys.

Budget and Budget Justification

Based upon a class size of 25 students and considering the sample size for the variable group to be 3 classes, the study will require the following resources:

1 Case Nitrile Gloves –	$ 73.50
Pipet Tips Starter Kit–	$ 65.00
Food Coloring –	$ 5.00
BioRad 1% Agarose Gel	$ 35.25
Carolina Biological Kit	$139.00
Elisa Immuno Explorer Kit –	$155.00
Total -	$472.75

The gloves will be used to ensure that the students use proper safety precautions when conducting biotechnology lab work. The pipet tips are needed to ensure that the students learn the proper techniques for pipetting to eliminate cross contamination of samples. The food coloring will be used to color water during the pipetting practice exercise. The agarose gel will be used to prepare gels when the students learn how biotechnology techniques can be used to study DNA. The Carolina Biological Kit will be used in the biotechnology exercise designed so students learn how the study of DNA can be used in a practical forensics application. The Elisa Immuno Explorer Kit will be used to demonstrate how antibodies can be detected upon exposure to various foreign invaders in the body.

Other supplies to be provided through Bench to Bedside:

Pipetting Station
Introduction to Gel Electrophoresis Locker

Permissions

Permission to conduct this action research will be requested from the principal of the high school through a written request via email.

Literature Cited

DeBoer, G. E. (2000). Scientific literacy: Another look at its historical contemporary meaning and its relationship to science education reform. *Journal of Research in Science Teaching, 37*(6), 582-601.

Gibson, H. L., & Chase, C. (2002). Longitudinal impact of an inquiry-based science program on middle school students' attitudes toward science. *Science Education, 86,* 693-705, online: www.interscience.wiley.com.

Harms, U. (2002). Biotechnology Education in Schools. *Electronic Journal of Biotechnology, 5*(3), 205-211, online: http://www.ejbiotechnology.info/content/vol5/issue3/teaching/01.

Kulik, J.A. (2003). Effects of using instructional technology in elementary education and secondary schools: What controlled evaluation studies say. Arlington, Virginia: SRI International.

Moore, R.W. & Foy, R.L.H. (1997). The Scientific Attitude Inventory: A Revision (SAI II). *Journal of Research in Science Teaching, 34*(4), 327-336.

Ong, E., & Ruthven, K. (2009). The effectiveness of smart schooling on students' attitudes towards science. *Eurasia Journal of Mathematics, Science & Technology Education, 5*(1), 35-45.

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: a review of the literature and its implications, *International Journal of Science Education, 25*(9), 1049-1079.

Postlehwait, J.H., & Hopson, J.L. (2006). *Modern Biology*. Austin, TX: Holt, Rinehart and Winston.

Tuan, H-L., Chin, C-C., & Shieh, S-H. (2005). The development of a questionnaire to measure students' motivation towards science learning*,* *International Journal of Science Education 27*(6), 639–654.

Walczak, M. M., & Walczak, D. E. (2009). Do student attitudes toward science change during a general education chemistry course? *Journal of Chemical Education, 86*(8), 985-991.

Yager, R.E., & Penick, J.E. (1986). Perceptions of four age groups toward science classes, teachers, and the value of science. *Science Education, 70*(4), 355-363.

Appendix 1

A Scientific Attitude Inventory

(Moore and Foy, 1997)

SAI II

WHAT IS YOUR ATTITUDE TOWARD SCIENCE?

There are some statements about science on the next three pages. Some statements are about the nature of science. Some are about how scientists work. Some of these statements describe how you might feel about science.

You may agree with some of the statements and you may disagree with others. That is exactly what you are asked to do. By doing this, you will show your attitudes toward science.

After you have carefully read a statement, decide whether or not you agree with it. If you agree, decide whether you agree mildly or strongly. If you disagree, decide whether you disagree mildly or strongly. You may decide that you are uncertain or cannot decide. Then, find the number of that statement on the answer sheet, and **CIRCLE** the:

> **A** if you agree strongly
>
> **B** if you agree mildly
>
> **C** if you are uncertain or cannot decide
>
> **D** if you disagree mildly
>
> **E** if you disagree strongly

EXAMPLE:

I would like to have a lot of money.

A B C D E

The person who circled this example agrees strongly with the statement, "I would like to have a lot of money."

Please respond to each statement and circle only ONE letter for each statement.

1. Good scientists are willing to change their ideas.

A   B   C   D   E

2. I would enjoy studying science.

   A **B** **C** **D** **E**

3. I may not make great discoveries, but working in science would be fun.

   A **B** **C** **D** **E**

4. Scientific work is useful only to scientists.

   A **B** **C** **D** **E**

5. Scientific ideas may be changed over time.

   A **B** **C** **D** **E**

6. Scientists are always interested in better explanation of things.

   A **B** **C** **D** **E**

7. Most people are unable to understand science.

   A **B** **C** **D** **E**

8. Working in a science laboratory would be fun.

   A **B** **C** **D** **E**

9. Some questions cannot be answered by science.

   A **B** **C** **D** **E**

10. When scientists have a good explanation, they do not try to make it better.

   A **B** **C** **D** **E**

11. Scientists should not criticize each other's work.

   A **B** **C** **D** **E**

12. Most people can understand science.

   A **B** **C** **D** **E**

13. Every citizen should understand science.

   A **B** **C** **D** **E**

14. Scientific questions are answered by observing things.

        A   **B**   **C**   **D**   **E**

15. Anything we need to know can be found out through science.

        A   **B**   **C**   **D**   **E**

16. A major purpose of science is to produce new drugs and save lives.

        A   **B**   **C**   **D**   **E**

17. If one scientist says an idea is true, all other scientists will believe it.

        A   **B**   **C**   **D**   **E**

18. Scientists must report exactly what they observe.

        A   **B**   **C**   **D**   **E**

19. Scientists have to study too much.

        A   **B**   **C**   **D**   **E**

20. I would like to be a scientist.

        A   **B**   **C**   **D**   **E**

21. The search for scientific knowledge would be boring.

        A   **B**   **C**   **D**   **E**

22. Only highly trained scientists can understand science.

        A   **B**   **C**   **D**   **E**

23. People must understand science because it affects their lives.

        A   **B**   **C**   **D**   **E**

24. Electronics are examples of the really valuable products of science.

        A   **B**   **C**   **D**   **E**

25. A major purpose of science is to help people live better.

        A   **B**   **C**   **D**   **E**

26. I would like to work with other scientists to solve scientific problems.

A   **B**   **C**   **D**   **E**

27. Scientists do not have enough time for their families or for fun.

A   **B**   **C**   **D**   **E**

28. Science tries to explain how things happen.

A   **B**   **C**   **D**   **E**

29. Scientific work would be too hard for me.

A   **B**   **C**   **D**   **E**

30. I do not want to be a scientist.

A   **B**   **C**   **D**   **E**

Science Lesson Plan

Title: A New Fingerprint

Key Questions: How is each individual's DNA unique? What is meant by a DNA digest using restriction enzymes? How can the biotechnology technique of gel electrophoresis be used to identify a crime suspect?

Science Subject: Biotechnology

Grade and Ability Level: Grades 11 and 12, Mainstream and Honors

Science Concepts: The lesson will begin with a review of the concept of DNA base pairs and sequencing. This lesson will then present the concepts of DNA splicing using restriction enzymes. Then the lesson will explain the biotechnology technique of gel electrophoresis which can be used to match DNA to a specific person, by running the digested DNA on a gel to separate the fragments.

Time Estimate: The lesson will take approximately 50 minutes.

Learning Styles: The lesson will involve students using both visual and kinesthetic learning.

Vocabulary: The key terms to be used and defined in the lesson include – base pairs, adenine, thymine, guanine, cytosine, restriction enzymes, gel electrophoresis, DNA fingerprint, length polymorphisms, and variable number tandem repeats (VNTR)

Lesson Summary: The lesson will cover how an individual's DNA is unique due to the sequence of the base pairs and the variations in length polymorphisms. The base pairs determine the sequence of amino acids in the production of proteins. This concept will be presented using a simulation game where the students identify a code presented by a DNA sequence. Then the concept of restriction enzymes will be presented by a short lecture, and finally, the concept of gel electrophoresis will be presented through a lab exercise where the students load a gel with the DNA of crime suspects to be compared with that of the DNA found at a crime scene. The students will then be asked to identify the criminal based upon the DNA fingerprint produced by the gel electrophoresis.

Learning Objectives: Students will be able to

1. Recognize and decode a unique sequence of DNA
2. Use a simulated restriction enzyme to cut DNA strands into various lengths due to the length polymorphisms
3. Read a DNA fingerprint from gel electrophoresis

These objectives relate to the Florida Next Generation Sunshine State Standard number SC.912.L.16.10.

Materials: The materials needed include:

       1 preprepared gel (ready to load with samples)/4 students
       1 micropipette / 2 students
       1 Crime Scene Investigator DNA kit per class

Background Information: DNA (deoxyribonucleic acid) is a double helix of nucleotide- adenine, thymine, guanine, and cytosine. The bases form a strand of coded information that is used to produce proteins. Ninety-eight percent of the DNA information does not code for anything, but is simply noncoding length polymorphisms, or variations in the length of the DNA molecule between the known genes. The length polymorphisms are often repeating base sequences, such as CACACA. The lengths of the repeated sequences vary among individuals and thus are referred to as variable number tandem repeats or VNTRs. When a restriction enzyme (a bacterial protein that recognizes short DNA sequences and cuts the DNA in or near the sequence) is used to cut a strand of human DNA, the length of the resulting fragments will vary among the DNA samples from different individuals (Postlehwait and Hopson, 2006).

     The DNA fragments can then be studied using gel electrophoresis. Gel electrophoresis is a process where nucleic acids or proteins are separated according to their size and charge using an electrical current which runs through a thick agarose gel once the DNA samples are loaded. The negatively charged DNA fragments migrate to the positively charged end of the gel and the smaller fragments move farther than larger fragments. The resulting pattern of bands is called a DNA fingerprint because it will be as unique as the individual themselves. As the number of VNTR loci that is analyzed increases, the possibility that two individuals will produce the same fingerprint is reduced. Thus, the students should be able to use the DNA fingerprints to identify a criminal based upon the matching of the various banding patterns produced on the gel (Postlehwait and Hopson, 2006).

Advance Preparation: In order to prepare for this lesson, 6 gels will need to be set up per class so that the students will load the samples to run the gel. In addition, the simulation exercise that involves the students demonstration of decoding of a DNA molecule will need to be prepared and copied, so that each student is able to demonstrate their understanding of DNA decoding and DNA digestion by restriction enzymes.

Procedure and Discussion Questions: The lesson will be presented according to the following procedure:

1. Each student will be given a strand of paper with a DNA molecule on it. Within the class, there will be four different DNA strands, whose nucleotide sequences differ. A key will be posted on the overhead projector that provides a letter for each DNA codon. Students will be asked to read their DNA strand by codons and assign the associated letter that matches with the codon. The DNA strand will be decoded and a message will emerge from the strand. (20 minutes)
2. A short demonstration will be provided about restriction enzymes and how they seek out specific sequences and then cut the DNA at or near these sites. The students will then be

asked to find certain sequences on their DNA strands and cut their DNA and see how the resultant fragments differ from the others at their lab table. (20 minutes)

3. The students will then be asked to load a gel with DNA samples from suspects along with the DNA that was found at the scene of a crime. The DNA will all be from the Crime Scene Kit purchased. They will then start the gel and write a short paragraph that explains what they will look for on the gel the next day and what will it mean. (10 minutes)

Assessment Suggestions:

1. The assessment for the first objective, that students should recognize and decode a unique sequence of DNA, will be the message produced by the students' decoding the DNA molecule. If students produce the proper message, they have decoded the DNA strand correctly.

2. The assessment for the second objective, simulating a restriction enzyme cutting the DNA strand into various lengths due to the length polymorphisms, will include the work product as the student is asked to demonstrate where their DNA will be cut by a restriction enzyme and how big will the resultant fragments be.

3. The assessment for the final objective, that the students be able to read a DNA fingerprint from gel electrophoresis, will be measured by the students' hands-on work. They will write a short paragraph that explains what they saw on the gel and what it means.

References:

Postlehwait, J.H., & Hopson, J.L. (2006). *Modern Biology*. Austin, TX: Holt, Rinehart and Winston.