The Effects of Adding Biotechnology Simulations and Labs to Traditional Molecular Genetics Instruction on the Knowledge and Attitudes of AP Biology Students

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Abstract: This study focuses on the effects of adding biotechnology simulations and labs to traditional molecular genetics instruction on the knowledge and attitudes of AP Biology students.

For the purpose of this study I will add activities that I learned about through the “Bench to Bedside” summer institute at University of Florida (CPET). Then I will measure the effects of the additional instruction with a variety of assessment tools that focus on knowledge and perception.

Rationale: Molecular genetics is a very difficult topic for many AP Biology students. Many don’t remember what they learned (or were not exposed to) in their previous biology class and therefore lack background knowledge to “hook” new ideas on to. I have never been completely satisfied with my normal mode of instruction which is as follows: Students read these chapters and complete teacher-designed study guides. Then I lecture, go over the study guides with them and watch and discuss some animations that come with the textbook that I use. Students also do Lab 6 from the AP Biology lab manual that goes along with this unit. However, there are some topics that are only covered by reading the chapter and doing the study guide, which may not be enough instruction for these concepts. In this study, I plan to use a variety of hands-on and virtual simulations given to me in the Bench to Bedside summer institute. I am also adding a PCR lab in addition to Lab 6 which is a required lab.

My first goal is to increase student knowledge in biotechnology. Biotechnology has been given fleeting attention in public schools. Public perception of biotechnology had “drifted far from reality” (Braun and Moses 2004). It is clear that both adults and high school students (in traditional science classes) have limited knowledge of biotechnology. I believe that using the simulations (both hands-on and virtual) will allow students to experience biotechnology activities that are not available in the day to day classroom. Using a simulation also allows students to repeat the experience until they “get it right” (Bergland, et. al., 2006). Simulations actively engage students. “Computer simulations can provide a bridge between theory and experience when the simulations and hands-on activities are closely coupled” (Richards, Barowy, and Levin 1992).

My second goal is to influence attitudes of biotechnology in my students. In my experience attitude is correlated with knowledge. I will use assessments that will tell me my students’ attitudes before and after instruction in biotechnology. Although science and technology have made most peoples’ lives better, many are suspicious, even fearful of it (Braun and Moses, 2004). People tend to fear the unknown. I am hoping to show that an increase in knowledge will lead to more positive attitudes toward biotechnology. Mueller, Knobloch, and Orvis (2009)
found that using hands-on activities and simulations led to increased knowledge and more positive views about biotechnology (than students who did not receive this type of instruction).

The purpose of this study is to use simulations and labs to augment the traditional instructional strategies for molecular genetics in AP Biology with the intention of increasing the knowledge and attitudes of AP Biology students.

**Action Research Intervention:** The molecular genetics unit of the AP Biology curriculum encompasses the structure of DNA, gene to protein and DNA technology and genomics. The activities I plan to use will enhance instruction of the objectives described below.

According to the AP Biology Topic Outline provided by the College Board (2009), Molecular Genetics includes the instructional objective of “Nucleic acid technology and applications.” This includes: a. current recombinant technologies, b. practical applications of nucleic acid technology, and c. legal and ethical problems that may arise from these applications.

A draft copy of the new curriculum framework for AP Biology for 2012-2013 from College Board (2010) uses the following standards that will include the activities I plan to use:

- **Essential Knowledge 3.A.1:** DNA, and in some cases RNA, is the primary source of heritable information.
  
  Learning Objective: The student can justify the claim that humans can manipulate heritable information by identifying at least two commonly used technologies.

- **Essential Knowledge 3.B.1:** Gene regulation results in differential gene expression, leading to cell specialization.
  
  Learning Objective: The student is able to explain how the regulation of gene expression is essential for the processes and structures that support efficient cell function.

  Learning Objective: The student can use representations to describe how gene regulation influences cell products and function.

My objectives are to increase knowledge and understanding of these objectives by enhancing my traditional instruction with more biotechnology activities.

In addition to the traditional types of instruction (see first paragraph of rationale) that I normally use, I will be using two virtual simulations: Click and Clone and virtual PCR. I am using the Click and Clone activity to reinforce their knowledge of Somatic Cell Nuclear Transfer, which is a way to clone organisms. The virtual PCR will be a way for them to practice what they have
learned about PCR, before they do the actual lab. General questions on both of these activities will be on the pre- and post- tests and the lab write-up for PCR (virtual PCR). I will be using 2 hands-on simulations: Microarrays (Dr. Lawrence’s activities) and a Science Take Out activity on Stem Cells. The purpose of these two activities is to reinforce what they have covered in lecture, by simulating real-world situations. Once again, there will be questions on the pre- and post- tests on these items. Lastly, I will be utilizing the assistance of the CPET staff at University of Florida to do a PCR lab called PV92 (this is the field trip mentioned in my budget). The lab will be graded with a lab write-up. I expect this lab will bring together the steps of PCR for the students and they will see how PCR is actually applied to solving problems. The lab activity will probably affect their attitudes the most, since they will be determining their own genotype for the Alu gene. I also hope that if students gain knowledge, it will positively affect their perceptions of biotechnology. I will probably have two classes of AP Biology and all of the students will be performing these activities during the month of November 2011 in my classroom and at the university.

**Connections to Bench to Bedside Summer Institute:** All of the additional activities I am using have come from my Bench to Bedside experience. Microarrays will be available through the equipment locker program and I will purchase the Stem Cell kits from Science Take Away. The PCR lab will be performed with the assistance of the CPET staff at the university.

**Data Collection and Analysis:** I will be using a variety of assessment tools matched to my goals. Quantitative information will be obtained using a Likert scale for the attitudes (please see the first draft of this survey on the last page of this document). Quantitative information about knowledge will be assessed using traditional pre- and post- multiple choice tests. I plan to use an item analysis on the multiple choice tests and I will grade Lab 6 using the key that is provided in the teacher’s lab manual on a simple percentage of answers correct basis. I will be using descriptive statistics to interpret my quantitative data. Qualitative information will be obtained by surveying the students with and teacher observations. I will be making notes as the students work through these activities about their comments and observations. I will interpret this data by connecting my findings with personal experience, and looking for patterns that emerge from the data analyses.

**Literature Cited:**


**Budget:** The money will be used to purchase a class set of the Stem Cell Kits and to pay for a sub and gas to get the students up to UF for the PCR Lab.

**Permission:** Students will need permission for the field trip to UF.
Student Survey
Attitudes Toward Biotechnology

1. Biotechnology is the application of science to solving real world problems.
2. I can describe at least 2 biotechnology applications used in health care today.
3. Most high school graduates have a basic understanding of biotechnology and its applications.
4. Stem cells are obtained from discarded embryos obtained through in vitro fertilization.
5. Stem cell research may use embryonic stem cells as well as adult stem cells.
6. Stem cells can be used to treat leukemia.
7. The only way to figure out your genetic makeup is to use a pedigree.
8. People can pay to have their genome sequenced.
9. Cloning is a process that can be used to make medicines.
10. Cloning can be used to grow transplantable tissue.
11. Microarrays are used to tell what genes a person has.
12. Microarrays are used to tell if you have been exposed to a particular disease.

1-strong disagree
2-disagree
3-neither agree nor disagree
4-agree
5-strongly agree
Biotechnology Education Action Research

Jane Beebe, MT (ASCP)
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Forest High School
Ocala, Florida
The purpose of this action research was to measure the effects of adding biotechnology simulations and labs to traditional molecular genetics instruction on the knowledge and attitudes of AP Biology students.
I added the following to my usual curriculum for teaching molecular genetics:

- Virtual simulations: Click and Clone and virtual PCR
- Hands on simulations: Science Take Out on Stem Cells
- Labs: Alu–PV92 PCR Lab (in addition to AP Biology Lab 6)
DNA Technology Pre-Test
AP Biology/Ms. Reuss

1. Which of the following has been produced by genetically modified organisms?
   a. Human insulin
   b. Human growth hormone
   c. Cancer drugs
   d. Growth factor for burn treatment
   e. All of the above

2. There are thought to be about ______ genes in a human cell.
   a. 20
   b. 46
   c. 5,000
   d. 20,000
   e. 3 billion

3. In recombinant DNA experiments, _____ is used to cut pieces of DNA, and _____ joins these segments to form recombinant DNA.
   a. a restriction enzyme, DNA ligase
   b. a restriction enzyme, a restriction enzyme
   c. a polymerase, DNA ligase
   d. DNA ligase, a restriction enzyme
   e. a transposon, a plasmid

4. Which of the following is cited as a possible risk of genetically modified crop plants?
   a. Allergen reactions
   b. Hybridization with wild relatives
   c. Creation of new pests that might be hard to control
   d. All of the above
   e. GM crops actually present no risk

5. Gel electrophoresis is used to:
   a. separate fragments of DNA
   b. clone genes
   c. cut DNA into fragments
   d. match a gene with its function
   e. amplify small DNA samples to obtain enough for analysis

6. DNA fingerprinting was used to determine whether even could be the father of Becky's baby. Which of the following would show that even is not the father? If _____ genetic fingerprint showed some bands not in _____ genetic fingerprint.
   a. even, the baby's
   b. Becky's, the baby's
   c. the baby's, even's
   d. the baby’s, Becky’s
   e. Becky’s, even's or Becky’s

7. Which of the following appear to have the most potential for use in therapeutic cloning?
   a. Adult stem cells
   b. Embryonic stem cells
   c. Exosomes
   d. Cartilage cells
   e. Hybridoma cells

8. Which of the following is a small piece of bacterial DNA used for gene transfer?
   a. Chromosome
   b. Plasmid
   c. Ribosome
   d. Restriction enzyme
   e. Virus

9. Which of the following is a technique used to make copies of DNA?
   a. Gel electrophoresis
   b. Gene cloning
   c. Polymerase Chain Reaction (PCR)
   d. Clone cell manipulation
   e. Shotgun method

10. Which of the following can be used to transform stem cells into differentiated cells like liver cells, for example?
    a. Restriction enzymes
    b. Promoters
    c. Reverse transcriptase
    d. Growth factors
    e. Vectors


Biotechnology Attitudes Survey

Please do not put your name on this survey:

A. What is genetic engineering?

B. What are some examples of genetic engineering?

C. Place a check mark in the column that best describes your reaction to the statement given:

Key: SA=Strongly Agree; A=Agree; N=Neither Agree nor Disagree; D=Disagree; SD=Strongly Disagree

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Test Results

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Mean, Median and Mode

Measures of Central Tendency

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### Breakdown of Topics

#### Breakdown of Question Topics

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### Percent Score

- **20**
- **40**
- **60**
- **80**
- **100**
- **120**
Data notes:

- I removed question one from the previous graph. The answer was “all of the above,” which I believe that most students picked out of not knowing versus the post-test where they put more thought into it.
- The Click and Clone activity did not have a question on the pre and post tests, so I simple asked: “What is SCNT?” before the activity and no one knew. I did not ask the question again until 4 weeks later when 68% answered the question correctly.
Conclusions:

- Student knowledge increased between pre- and post-tests.
- Student knowledge increased between questions that had biotechnology activities attached to them versus questions that had been taught by lecture/study guides alone.
- AP Biology students had generally positive attitudes both before and after the activities.
Yes, I will try to add as many of these activities as possible—time permitting—to my molecular genetics curriculum. These activities are enjoyed by the students and increase knowledge.
What would I change?

I would try to target more concepts and add more activities as needed. Bench to Bedside and ICORE give teachers many activities that can be used in biotechnology education.
### Attitudes Survey Results

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<tr>
<th>Question</th>
<th>Strongly Agree Before</th>
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General Knowledge AP Bio Lab 6 Stem Cell Take Out Click and Clone

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1. Which of the following has been produced by genetically modified organisms?
   a. Human insulin
   b. Human growth hormone
   c. Cancer drugs
   d. Growth factor for burn treatment
   e. All of the above

2. There are thought to be about ______ genes in a human cell.
   a. 23
   b. 46
   c. 5,000
   d. 20,000
   e. 2.9 billion

3. In recombinant DNA experiments, ______ is used to cut pieces of DNA, and ______ joins these segments to form recombinant DNA.
   a. A restriction enzyme...DNA ligase
   b. A transposon...a restriction enzyme
   c. A plasmid...DNA ligase
   d. DNA ligase...a restriction enzyme
   e. A transposon...a plasmid

4. Which of the following is cited as a possible risk of genetically modified crop plants?
   a. Allergic reactions
   b. Hybridization with wild relatives
   c. Creation of new pests that might be hard to control
   d. All of the above
   e. GM crops actually present no risks

5. Gel Electrophoresis is used to:
   a. Separate fragments of DNA
   b. Clone genes
   c. Cut DNA into fragments
   d. Match a gene with its function
   e. Amplify small DNA samples to obtain enough for analysis

6. DNA fingerprinting was used to determine whether Evan could be the father of Becky’s baby. Which of the following would show that Evan is NOT the father? If _____ genetic fingerprint showed some bands not in ______ genetic fingerprint.
   a. Evan’s…the baby’s
   b. Becky’s…the baby’s
   c. The baby’s…Evans
   d. The baby’s…Becky’s
   e. The baby’s…Evan’s or Becky’s
7. Which of the following appear to have the most potential for use in therapeutic cloning?
   a. Adult stem cells
   b. Somatic cells
   c. Gametes
   d. Cancer cells
   e. Embryonic stem cells

8. Which of the following is a small piece of bacterial DNA used for gene transfer?
   a. Chromosome
   b. Plasmid
   c. Ribosome
   d. Restriction enzyme
   e. Virus

9. Which of the following is a technique used to make copies of DNA?
   a. Gel electrophoresis
   b. Gene cloning
   c. Polymerase Chain Reaction (PCR)
   d. Stem cell manipulation
   e. Shotgun method

10. Which of the following can be used to transform stem cells into differentiated cells like liver cells, for example?
    a. Restriction enzymes
    b. Plasmids
    c. Reverse transcriptase
    d. Growth factors
    e. Vectors
The Effects of Adding Biotechnology Simulations and Labs to Traditional Molecular Genetics Instruction on the Knowledge and Attitudes of AP Biology Students

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The Effects of Adding Biotechnology Simulations and Labs to Traditional Molecular Genetics Instruction on the Knowledge and Attitudes of AP Biology Students

Abstract

The purpose of my action research was to evaluate the effects of adding biotechnology simulations and labs to traditional molecular genetics instruction on the knowledge and attitudes of AP Biology students.

I used two virtual simulations-Click and Clone and Virtual PCR; one hands-on simulation-Science Take Out Stem Cell Activity; and 2 labs-AP Biology Lab 6 and Alu-PV92 PCR lab. I added these to my traditional method of instruction using lecture and study guides (AP Lab 6 is also traditionally used).

My data clearly shows that the students’ knowledge of molecular genetics increased as measured with a pre and post test. Some questions were on material that was covered with the additional activities and some were on material that was covered by lecture and study guides alone. There was also a difference there as the students show more gains on the questions associated with the activities. My AP Biology students had generally positive attitudes both before and after instruction.

In conclusion, using biotechnology simulations and labs increased knowledge over traditional instruction on molecular genetics topics. Attitudes were generally positive both before and after instruction.
Rationale: Molecular genetics is a very difficult topic for many AP Biology students. Many don’t remember what they learned (or were not exposed to) in their previous biology class and therefore lack background knowledge to “hook” new ideas on to. I have never been completely satisfied with my normal mode of instruction which is as follows: Students read these chapters and complete teacher-designed study guides. Then I lecture, go over the study guides with them and watch and discuss some animations that come with the textbook that I use. Students also do Lab 6 from the AP Biology lab manual that goes along with this unit. However, there are some topics that are only covered by reading the chapter and doing the study guide, which may not be enough instruction for these concepts. In this study, I used a variety of hands-on and virtual simulations given to me in the Bench to Bedside summer institute. I also added a PCR lab in addition to Lab 6 which is a required lab.

My first goal was to increase student knowledge in biotechnology. Biotechnology has been given fleeting attention in public schools. Public perception of biotechnology had “drifted far from reality” (Braun and Moses 2004). It is clear that both adults and high school students (in traditional science classes) have limited knowledge of biotechnology. I believe that using the simulations (both hands-on and virtual) allowed students to experience biotechnology activities that are not available in the day to day classroom. Using a simulation also allowed students to repeat the experience until they “got it right” (Bergland, et. al., 2006). The simulations actively engaged students. “Computer simulations can provide a bridge between theory and experience when the simulations and hands-on activities are closely coupled” (Richards, Barowy, and Levin 1992).

My second goal was to influence attitudes of biotechnology in my students. In my experience attitude is correlated with knowledge. I used assessments that told me my students’ attitudes before and after instruction in biotechnology. Although science and technology have made most peoples’ lives better, many are suspicious, even fearful of it (Braun and Moses, 2004). People tend to fear the unknown. The data showed that an increase in knowledge led to more positive attitudes toward biotechnology. Mueller, Knobloch, and Orvis (2009) found that using hands-on activities and simulations led to increased knowledge and more positive views about biotechnology (than students who did not receive this type of instruction).

The purpose of this study was to use simulations and labs to augment the traditional instructional strategies for molecular genetics in AP Biology with the intention of increasing the knowledge and attitudes of AP Biology students.
**Action Research Intervention:** The molecular genetics unit of the AP Biology curriculum encompasses the structure of DNA, gene to protein and DNA technology and genomics. The activities I used to enhance instruction of the objectives are described below.

According to the AP Biology Topic Outline provided by the College Board (2009), Molecular Genetics includes the instructional objective of “Nucleic acid technology and applications.” This includes: a. current recombinant technologies, b. practical applications of nucleic acid technology, and c. legal and ethical problems that may arise from these applications.

A draft copy of the new curriculum framework for AP Biology for 2012-2013 from College Board (2010) uses the following standards that will include the activities I plan to use:

- **Essential Knowledge 3.A.1:** DNA, and in some cases RNA, is the primary source of heritable information.
  - Learning Objective: The student can justify the claim that humans can manipulate heritable information by identifying at least two commonly used technologies.

- **Essential Knowledge 3.B.1:** Gene regulation results in differential gene expression, leading to cell specialization.
  - Learning Objective: The student is able to explain how the regulation of gene expression is essential for the processes and structures that support efficient cell function.
  - Learning Objective: The student can use representations to describe how gene regulation influences cell products and function.

My objectives were to increase knowledge and understanding of these objectives by enhancing my traditional instruction with more biotechnology activities.

In addition to the traditional types of instruction (see first paragraph of rationale) that I normally used, I included two virtual simulations: Click and Clone and virtual PCR. I used the Click and Clone activity to reinforce the students’ knowledge of Somatic Cell Nuclear Transfer, which is a way to clone organisms. The virtual PCR was included so students could practice what they had learned about PCR, before they did the actual lab. General questions on both of these activities were on the pre- and post- tests and the lab write-up for PCR (virtual PCR). I used a hands-on simulation which was the Science Take Out activity on Stem Cells. The purpose of this activity was to reinforce what they had heard in lecture, by simulating real-world situations. Once again, there were questions on the pre- and post- tests on this activity. Lastly, I utilized the assistance of the CPET staff at University of Florida to do a PCR lab called PV92 (this is the field trip mentioned in my budget). Unfortunately no results were obtained...
from this lab because the electrophoresis did not work. The students did enjoy the lab and saw
the steps of PCR in action, as well as, how the products of PCR are then used to obtain data. I
still believe the students’ attitudes were positively affected due to the connections established
with the knowledgeable presenter from University of Florida. Two classes of AP Biology
performed these activities in November 2011 in my classroom and at the university.

**Connections to Bench to Bedside Summer Institute:** All of the additional activities I used came
from my Bench to Bedside experience. I purchased the Stem Cell kits from Science Take Away.
The PCR lab was performed with the assistance of the CPET staff at Forest High School.

**Data Collection and Analysis:**

**Attitudes Survey:** I have attached the attitudes survey and the graph of the results. I only
tabulated the results of the agree/disagree questions on the graph. The results show that the
students had positive attitudes both before and after the intervention, but the attitudes were
slightly more positive afterwards.

**Pre-Test and Post-Test Results:** A copy of the test is included with the other documents.
Students scored higher on all of the questions except the first one. I believe the “all of the
above” response was automatically chosen by many of the students on the pre-test. The
incorrect response shows that they were thinking more, but not always remembering all of the
examples we discussed on the post-test. Two other graphs are included regarding the pre-test
and post-test: Measures of Central Tendency and Breakdown of Question Topics. The
Breakdown of Question Topics shows that gains were made for each intervention technique.

**Literature Cited:**

Outline. [www.collegeboard.com](http://www.collegeboard.com)

Bergland, M., Lundeberg, M.A., Klyczek, K., Sweet, J., Emmons, J., Martin, C., Marsh, K., Werner,
American Biology Teacher, 68(2), 77-82

be relevant and effective?* Bern 11, Switzerland, BIOLINK and London, United Kingdom,
Department of Life Sciences, Kings College


**Budget:** The money was used to purchase a class set of the Stem Cell Kits and to pay for a sub and gas to get the students up to UF for the PCR Lab.

**Permission:** Students completed permission slips for the field trip to UF. Dr. Houda Darwiche also completed paperwork that permitted her to visit the Forest High School campus.

**Modifications from the Original Proposal:**
The only modification to my original proposal was that I was going to do a microarray simulation with my students. I was not able to fit that in, but I hope to do this in the future.

**Learnings from my Action Research:** All of the interventions worked in the sense that they increased my students’ knowledge and improved their attitudes regarding biotechnology. Next time, I think I would have them do some of the virtual simulations at home with a questions sheet, so that I could make more time for other activities during class. I learned that it is not too difficult to get real data from the activities I do with my students to assess the effectiveness of those activities.

**Dissemination:** I meet with a group of teachers for lunch every day in my classroom, and shared my research with them, as well as my principal. Since I am a biology teacher, it has been difficult this year to do much more because of the implementation of the new standards and preparing for the state exam. I may investigate publishing this summer, if I find the process to be easy and straight forward.
Measures of Central Tendency

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