IMPACT OF BIOTECHNOLOGY LABS ON HIGH SCHOOL BIOLOGY STUDENTS

by

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In presenting this professional paper in partial fulfillment of the requirements for a master's degree at Montana State University, I agree that the MSSE Program shall make it available to borrowers under rules of the program.

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DEDICATION

This project would not be possible without the tremendous support of Susan Reinhardt, Education Outreach Coordinator at University of Georgia College of Agriculture and Environmental Science and Ina Claire Webb, tireless mentor to all science educators in Tift County, Georgia and beyond. Special gratitude also goes to the Tift County Foundation for Educational Excellence for providing grant funds for the Vernier LabQuest Equipment and to the University of Georgia for providing Bio-Rad Explorer Kits and loan of lab equipment for classroom use.

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ABSTRACT

There is a growing interest and emphasis on teaching biotechnology methods and concepts to high school level students in order to help prepare them to be able to participate in highly technological careers. Numerous biotechnology professional development programs exist for science teachers to gain knowledge and skills that are necessary to teach biotechnology. While it is an easy transition to teach biotechnology methods in advanced and AP level courses, there is uncertainty about the limitations and accommodations that will be necessary to incorporate biotechnology labs into a regular high school biology classroom with 28 students or more of various levels and exceptionalities. The additional expense and time necessary to incorporate biotechnology are justified if students gain increased conceptual understanding and demonstrate improved attitude toward science as a result of the labs. The primary question I sought to answer with this project was what are the effects of incorporating biotechnology labs on high school students' understanding of molecular biology concepts? Secondary questions related to the project are: What were the effects of incorporating biotechnology labs on students' interest in science, students' confidence in their abilities to do science, and on my teaching practices? The sequence of biotechnology labs that occurred within the curriculum of compulsory high school biology were quantitative protein analysis of food, DNA fingerprinting, pGLO bacterial transformation, and GMO investigation of food. The labs utilized Vernier Probeware and Bio-Rad Explorer kits. Conceptual understanding of molecular biology concepts was assessed using student developed concept maps and free-response questions. Anonymous student surveys and one-on-one student interviews were used to assess attitude toward science, which is defined in this project as interest, confidence, and relevance. Results for improved attitude were inconclusive; however gains in conceptual understanding were substantial with the biotechnology labs.

INTRODUCTION AND BACKGROUND

Science Education Reform and Biotechnology

Science education reform in the United States continues to be a paramount effort

at all levels. Arden Bement, former Director of the National Science Foundation (NSF),

in his 2009 speech to the American Association for the Advancement of Science (AAAS)

Vision and Change in Undergraduate Biology Education Conference stated: "The status

quo in science education is not achieving the results we need." (AAAS, 2009, p.7).

Bement advocates efforts to strengthen science and engineering research and education to

meet increasing technological workforce demands and to "resolve America's greatest

challenges in energy, environment, economy, security, and health" (Bement, 2009, p.1).

As an educator, I feel the responsibility to participate with the national goals of

science education reform. The status quo in my biology teaching methods is not

achieving the results that my students need. Many of my students are at or below basic

scientific literacy and they are difficult to motivate because they see no relevance in

biology class to their lives. Often my students reveal that their goal is to get through

biology or give up. Looking for avenues to inspire interest in learning biology for my

students, I recently participated in a week long biotechnology workshop for teachers. The

workshop provided experience with industry standard biotechnology labs and was offered

through a biotechnology education initiative in my state sponsored by Georgia Bio. As a

result of the workshop, I gained a deeper understanding of molecular biology concepts

and real world biotechnology processes. In addition to the training another co-sponsor,

the University of Georgia, provided the biotechnology lab kits for my classroom and the

use of expensive lab equipment such as micropipettes, gel electrophoresis trays, a PCR

thermocycler, and the like for loan. In further support, the Tift County Foundation for

Educational Excellence provided grant funds for the purchase of Vernier LabQuest data

loggers and probeware. The workshop experience had the effect of boosting my

confidence and excitement to include the labs into my high school biology courses. If I

have become excited and empowered through this experience of learning new lab

techniques, could my biology students become more interested and therefore, motivated

to learn science through similar exposure to biotechnology labs?

Traditionally, biotechnology labs only occur in Advanced Placement or other

honors level biology courses in high school (Aschbacher, Li, & Roth, 2010). If we want

to improve the scientific literacy of the students at or below basic scientific literacy, then

it follows that biotechnology labs should occur at the compulsory level. Engaging all

students with relevant applications in science in order to provide a pathway to scientific

career choices is at the heart of my personal values as a science educator. Incorporation

of biotechnology labs into regular high school biology classrooms can serve to provide

access for all students to quality experiences that foster scientific literacy and that ignite

interest in science.

My goals for this project were to systematically study the effect on my students in

terms of conceptual understanding and attitude toward science as a result of

implementing biotechnology labs as part of the biology curriculum. I also sought to gain

insight into the factors that affect attitude toward science as part of motivating students to

achieve in science to and reflect on my own professional practice. An additional outcome

of this project will be to provide a rationale for the inclusion of biotechnology labs into

the biology curriculum at my high school and continued efforts in biotechnology professional development for educators at my school.

Research Questions

Primary Question: What are the effects of incorporating biotechnology labs on the understanding of molecular biology concepts? Secondary Questions: What are the effects of incorporating biotechnology labs on students' interest in science? What are the effects on incorporating biotechnology labs on students' confidence in their scientific abilities? What are the effects of incorporating biotechnology labs on my teaching practices?

CONCEPTUAL FRAMEWORK

As an educator, I recognize the performance gap that exists between successful students in science and the large number of students that are below basic proficiency. Often it is the experiences that set the stage for students to gain a context to begin to build conceptual understanding at a proficient level. Motivation to learn science at any level is linked to attitude toward science in terms of interest, relevance and confidence in abilities to do science (Taraban, Box, Meyers, Pollard, & Bowen, 2007). Biotechnology labs in the high school biology classroom can offer the experience needed to build confidence and the relevance to gain the students' interest in science in order to increase conceptual understanding of important molecular concepts in biology.

Performance Gap in Science

The rationale for incorporating biotechnology labs into the regular high school biology curriculum is to support the national goals of preparing students for the increasingly technological workforce demands (Bement, 2009). Cora Marrett (2009), the acting director of the NSF, reinforces the call for us to strive to get all students involved in Science, Technology, Engineering, and Mathematics (STEM) careers where women and minorities remain less involved in order to prepare all for a high tech workforce. The American Association for the Advancement of Science (AAAS) leads the science education reform effort with recommendations to promote increased appreciation of science, to increase real-world application of content, to focus on conceptual understandings, engage passion, and include students as active partners (AAAS, 2009).

The U.S. is a member of the Organisation for Economic Co-Operation and Development (OECD) which is a global partnership of thirty-one countries that serves to support sustainable economic development around the world. In *The High Cost of Low Educational Performance* (OECD, 2010), economic researchers link cognitive skills of high school students as an important factor in future economic growth. International comparison of cognitive skill level related to math and science literacy among member and non-member countries is achieved through use of the Program for International Student Assessment (PISA). Comparison of averages using science literacy scores for the 2006 PISA reveals that the U.S. average score (489) is below the combined OECD countries' average score (500). When the percentages of students in the 90th percentile were compared, the U.S. percentage was higher than the combined average of OECD countries, (Baldi, Jin, Skemer, Green, & Herget, 2006). The U.S. is fostering advanced

scientific literacy for many upper level achieving students, but that feat is offset by the

evidence that we are not fostering basic scientific literacy for a much greater percentage

of our students. Our concern as we strive to meet national and global challenges is how to

bridge the performance gap for the greater percentage of our students at or below the

lowest level of scientific literacy. One important factor related to students' motivation to

learn science is attitude.

<u>Significance of Attitude Toward Science</u>

Attitude can play a major role in the students' motivation to learn science

(Aschbacher, 2010; Kidman, 2009; Taraban, 2007). For the purposes of this project,

attitude is not defined as approval or disapproval of genetic engineering and related

issues. The intent for increased exposure to biotechnology is to equip students with

knowledge and understanding so they are confident in their ability to enter into critical

debate and substantiate their positions on the impact of biotechnology on society, not to

indoctrinate students. In fact, numerous studies have been cited by researchers that show

increased exposure to biotechnology does not increase the acceptance toward specific

human, medical, environmental, or medical applications of biotechnology (Dawson,

2007). For this project, attitude is defined as interest and confidence. Interest will be

demonstrated by observed engagement, further questioning, intention to take more

sciences courses and ultimately the intention to pursue a science career path choice.

Confidence in scientific abilities is a factor that also affects attitude and student learning.

Researchers looking for factors that affect students' persistence in pursuing a scientific

pathway found that erosion of confidence in high school level science courses was a primary factor for students shifting to other pursuits (Aschbacher, Li, & Roth, 2010).

In a 2009 study of attitude toward biotechnology in high school students, Kidman uncovered issues of interest toward science and found that students related they did not take non-compulsory biology courses as they were not interested and did not feel the course would be connected to their lives. This is an especially important insight for biology teachers as biology is typically a compulsory science subject in high school, but oftentimes it is the last required science course high school students take. This puts the biology course at a critical junction for students to continue or to not continue pursuit of scientific interests or a scientific career (AAAS, 2009; Kidman, 2009). How do we generate interest in non-compulsory science classes? Kidman's (2009) surveys revealed one especially profound student response: That the topics are not boring, only the teacher's methods. Other common suggestions by students indicated they want to explore controversial topics and participate in cutting-edge technology, like those they see in movies and TV shows, such as CSI. Biotechnology labs will offer students the experience using those high-tech methods.

<center>Biotechnology Curriculum</center>

Biotechnology is defined as the integration of biology and engineering; that is, techniques and technology used to study and manipulate living organisms with an emphasis on molecular biological concepts (Kreuzer & Massey, 2008, p.3). Biotechnology labs as a method of instruction within the secondary biology curriculum as described by both the National Science Education Standards (NRC, 1996) and the

Georgia Performance Standards (Georgia Department of Education, 2006) can offer real

world applications using integrated scientific content and cutting-edge tools of science to

gain conceptual understandings. A frequent criticism of incorporating biotechnology labs

into what some perceive as an already overcrowded biology curriculum is that there is no

time for it (Steele & Aubusson, 2004). I argue that due to the integrated nature of

biotechnology applications, nearly all of the content standards from the Life Science Core

Ideas for grades 9-12 of the 2010 draft of the new National Science Education Standards

(NRC, 2010) can be addressed as part of implementing biotechnology labs over a four

week period as part of a regular biology course. For example, the pGLO Bacterial

Transformation lab integrates topics related to prokaryotic cell structure and metabolism,

adaptation to environment, DNA structure and function, genetic expression, genetic

engineering, chemical properties, media preparation and aseptic technique. Furthermore,

biotechnology labs will enhance development of the four key strands of proficiencies

students need to develop as part of the goals of science and engineering education laid

out by the Committee on Conceptual Framework for New Science Education Standards

(NRC, 2010, pp.2-6):

1. Knowing, using, interpreting scientific explanations of the natural world

2. Generating and evaluating scientific evidence and explanations

3. Understanding the nature and development of scientific knowledge; and

4. Participating productively in scientific practices and discourse.

When comparing achievement results between traditional methods of instruction

(lecture, paper models, and manipulatives) with true laboratory methods using technology

and organic materials, the nature of the assessment task and the targeted level of

understanding determine the specific benefits revealed. The results of a study by Taraban, Box, Myers, Pollard, and Bowen (2007) that compared traditional methods of instruction with biotechnology methods with high school biology students showed slight improvement in factual recall, equal improvement in critical thinking, and significant improvement in process skill development using a written test. Surveys using Likert scales and open responses elicited further differences between the two methodologies: A significantly higher number of students perceived they applied critical thinking and process skills during the labs and a higher number of students were able to articulate content that they learned. The ability to articulate scientific understanding requires confidence and experience with materials that offer context and opportunity for students to explain outcomes (Taraban et al, 2007).

Another study implemented by Stolarsky Ben-Nun and Yarden (2009) with high school biology students that participated in a teacher-led outreach biotechnology laboratory reported only a 3 % increase in knowledge of DNA and protein synthesis; however the labs resulted in an 18 % increase in procedural understanding of biotechnology methods including restriction enzyme digest, gel electrophoresis, polymerase chain reaction, and transformation. The most significant outcome was a 36 % gain in students' accurate visual representation of DNA and molecular processes. The small gain in knowledge as a result of the labs could be interpreted to imply that students will gain factual knowledge within the normal classroom instruction; in this study the knowledge was high before the lab activities due to prior instruction. How the facts are visualized by students can lead to alternative conceptions that are not scientifically accurate, difficult to uncover, and persistent unless explicitly addressed (National

Academy of Science, 2005). The rationale for students to participate in biotechnology lab experiences lies in the evidence of significantly improved procedural understanding, accurate visual representation of molecular genetic structure and processes, and ability to articulate scientific concepts.

METHODOLOGY

Participants

The classes chosen for the capstone project were two high school biology classes consisting of 24 and 28 students that meet every day for ninety-minute blocks. The students were college preparatory and technical preparatory diploma seekers. All of the students were in 10th grade and with one exception, taking high school biology for the first time. The mix of students is typical for our high school in classes that are required for graduation. There were only four honor students in one class because our school also offers 9th grade Honor's Biology and AP Biology. The special education status of two of the students includes specific learning disabilities. English Language Learners (ELL) were served in a sheltered instruction biology class and were not in either of these two classes. The demographics are summarized in Table 1.

Table 1
Classroom Demographics

Race	Latino	African American	Caucasian	Asian	Multi
2nd Block n=24	13%	25%	58%	0%	4%
3rd Block n=28	4%	50%	39%	4%	3%
Total n=52	8%	38%	48%	2%	4%

Sub Groups	ESOL		SPED		Gifted
Total n=52	0%		4%		8%

Gender	Male		Female		
2nd Block n=24	29%		71%		
3rd Block n=28	68%		32%		
Total n=52	50%		50%		

These two classes were chosen for the capstone project because at least twenty-five percent of the 10th grade biology students were at a high risk for failure due to low socioeconomic level and being below 10th grade reading level, some as low as the 7th grade reading level. Table 2 summarizes the students' Lexile reading level scores.

Table 2
Lexile Reading Levels of Students

	7th	8th	9th	10th	11th	12th
2nd Block n=24	0%	8%	17%	4%	33%	38%
3rd Block n=28	7%	3%	14%	18%	29%	29%
Total n=52	4%	6%	15%	11%	31%	33%

One student in this group remarked that he had never passed a science test before in his life. I need to make foundational changes in my instruction in order to promote conceptual understanding especially for these students. The school is the only high school

in the county and serves a population of 42,000. In our system, 53% of the students

qualify for free or reduced meals. The research methodology for this project received an

exemption by Montana State University's Institutional Review Board and compliance for

working with human subjects was maintained.

Intervention

Lab experiences are an essential component of the high school biology curriculum

as the hands-on activities give students a practical context to make the abstract content

meaningful. Despite the inclusion of the traditional biology manipulative activities and

labs offered during instruction of abstract molecular topics, my students' unit and

standardized test scores remained in the dismal range, especially for the low level ability

learners. Worse, I have witnessed apathy in some of my students that can increase

steadily as the semester proceeds toward the end of course testing. With the intent to

improve student achievement, I implemented a series of biotechnology laboratory

activities using Vernier Probeware and Bio-Rad Explorer Kits and systematically

assessed the effect of the labs on students' attitude toward science and students'

conceptual understanding. A key distinction between the traditional labs and the

biotechnology labs was that the biotechnology labs incorporated appropriate scale

measurements, such as microliters; with industry standard tools, such as micropipettes;

and techniques, such as gel electrophoresis. In traditional labs, "High school students are

expected to master molecular concepts but do not participate in labs at the appropriate

scale" (W. Dustman, personal communication, June 13, 2011).

All units were based upon Georgia Performance Standards for secondary biology and National Science Education Standards and utilize the Learning Focused Schools' Acquisition Lesson Plan Format as required by our school system. As well as unit pre and post assessment, each topic within a unit had an activating strategy, vocabulary preview, instructional strategies, assessment prompts, and summarizing strategies. A sample lesson plan is attached in Appendix G. The following biotechnology labs were implemented as part of the treatment units:

1. Quantitative testing for proteins using Bradford protein assay

2. Forensic DNA Fingerprinting

3. pGLO bacterial Transformation

4. GMO Investigation of Foods

The biology curriculum sequence with units and data collection plan is summarized as the Capstone Project Timeline below in Table 3.

Table 3
Capstone Project Timeline

Week	Start Date	Topics and Labs	Assessment
1	9/07	Pre Treatment Unit I: Cells	Cells Concept Map 1
		Lab: Observing cells with light microscope	Post lab mini survey and interviews
2	9/13	Lab: Measuring osmosis in eggs	
3	9/20	Lab: Measuring rate of photosynthesis (Guided Inquiry)	Post lab mini survey and interviews
4	9/27	Lab: Observing mitosis in plant cells	
5	10/04	Mid Term Exams	Cells Concept Map 2 F/R Post assessment Biology Department Benchmark Test
6	10/11	Treatment Unit II: Chemistry of Life Labs: Analyzing food for carbohydrates, lipids, and proteins (qualitative) and Bradford protein assay (quantitative)	Biochem Concept Map 1 Post lab mini survey and interviews
7	10/19	Lab: Comparing rates of enzyme activity (Guided Inquiry)	Post lab mini survey and interviews Biochem Concept Map 2 F/R Post assessment
8	10/25	Treatment Unit III: Molecular Genetics Lab: Analyzing DNA fingerprinting	Molecular Genetics Concept Map 1 Post lab mini survey and interviews
9	11/01	Lab: Bacterial transformation with pGLO Lab: GMO Investigation	Post lab mini survey and interviews Molecular Genetics Concept Map 2 F/R Post assessment

Data Collection

The project consisted of three instructional units that were implemented with a

one semester high school biology class in the fall of 2010. The first unit of the project

was a non-treatment unit and was used for comparison to the subsequent treatment units.

All three units were initiated with student constructed concept maps as pre assessments to

evaluate conceptual understandings. Formative assessment occurred throughout the unit

and specifically during multi-day labs. For example, after completing a day one lab

activity, students anonymously recorded responses to two questions on a half sheet of

paper: "What did you learn today as a result of the lab activity?" and "What did you not

understand today during the lab?" Student responses were addressed at the next class

meeting. Post unit assessments consisted of student constructed concept maps and open

ended discussion questions. Student interest surveys occurred at the beginning of the

course and at the end of the course. Post lab mini surveys occurred after each lab and

one-on-one student interviews were conducted with four students at the completion of

each biotechnology lab. The Data Triangulation Matrix in Table 4 summarizes the focus

questions of the capstone project and relates the data sources for each question.

Table 4
Data Triangulation Matrix

Focus Questions	Data Source 1	Data Source 2	Data Source 3
Primary Question: 1. What are the effects of incorporating biotechnology labs on the understanding of molecular biology concepts?	Pre and post unit concept maps for both nontreatment and treatment units	Post unit free response questions for both nontreatment and treatment units	Post lab student interviews
Secondary Questions: 2. What are the effects of incorporating biotechnology labs on students' interest in science?	Pre and post attitude toward science survey	Post lab mini surveys	Post lab student interviews
3. What are the effects of incorporating biotechnology labs on students' confidence in their scientific abilities?	Pre and post attitude toward science survey	Post lab mini surveys	Post lab student interviews
4. What are the effects of incorporating biotechnology labs on my teaching practices?	Daily teacher observation and reflection log	Post lab mini surveys	Post lab student interviews

<u>Concept Maps</u>

Concept maps were used as pre assessments and as post assessments to reveal students' conceptual framework. The scoring rubric can be found in Appendix A. Scoring of the concept maps is based upon the work of Martin, Mintzes, and Clavijo (2000). Points were assigned to individual concept maps for the following categories: each concept (term) =1 point; number of relationships = 1 point; each additional branch = 3 points; each hierarchy (level) = 5 points; and each cross-link (interrelationship) = 10 points. Students' initial assessment (map 1) and post assessment (map 2) concept maps were compared using the scoring guidelines above. Students gained experience with the development of concept maps as pre and post unit assessments in previous units so that there was a minimal difference in scores related to a learning curve in the skill of constructing concept maps to represent learning

<u>Free Response Assessment Questions</u>

Free response assessment questions were used as summative assessments at the end of each unit and allowed for comparison between traditional labs and the biotechnology labs within each unit. Each free response question was focused on Georgia Performance Standards and National Science Education Standards for secondary biology. Students were given thirty minutes to complete the task and directed to answer each question to the best of their knowledge and experience using three or more sentences. Students were encouraged to use diagrams to help explain their answers. The responses of each question were evaluated separately and assigned a score based upon the following categories: +2 for significant knowledge; +1 for some relevant knowledge; 0 for no

relevant knowledge; and -1 for erroneous knowledge (Angelo & Cross, 1993). Examples

of free response questions are found in Appendix B. When alternative conceptions were

revealed on students' responses, explicit feedback strategies were implemented. One way

this was accomplished was by typing up all students' responses to the free response

question as true or false questions along with scientifically correct versions as a quick

quiz the next day followed by review. In this way persistent preconceptions that were in

opposition to scientific concepts, despite instruction were targeted and redirected.

Student Surveys and Interviews

Anonymous student surveys designed to assess student attitudes toward science in

terms of interest, relevance, and confidence were conducted at the beginning of the fall

semester and at the completion of the biotechnology treatment units. The questions were

adapted from a study conducting a field test of science curriculum (Kaelin et al, 2007).

The pre and post student attitude toward science is found in Appendix C. After the

completion of each lab for the non treatment and treatment units, all students were given

a post lab mini survey to formatively assess students' confidence in understanding,

interest, and perceived usefulness of the lesson. A five-point Likert scale was utilized for

students' responses on all surveys. A response of "strongly agree" was scored as a 5,

"agree" was scored as a 4, "neutral" was scored as a 3, "disagree" was scored as a 2, and

"strongly disagree" was scored as a 1. Mean scores for each question were calculated and

questions were grouped into three attitude factor categories of relevance, confidence, and

interest. The post lab mini survey additionally elicited comments from students and is

found in Appendix D. Informal student interviews were conducted with four individual

students after each lab activity to allow for elaboration of students' interest and

confidence in understanding of the lab concepts. Sample interview questions are found in

Appendix E. Students were chosen for one-on-one interviews by picking names randomly

out of a sack that contained all students' names. Once a student completed an interview,

that name was removed from the pool of names to be used for future interviews.

Teacher Reflection

I recorded my daily observations and reflections in the Daily Teacher Reflection

Log to monitor and record how my students responded to methods of instruction and how

I responded to my students. The format of the reflection log is found in Appendix F.

DATA AND ANALYSIS

Conceptual Understanding

In secondary biology classes, a number of students struggle with concepts related

to chemistry of life and molecular genetics due to the abstract nature of the content and

perceived detachment to any application to their lives. Implementing biotechnology labs

as part of the secondary biology curriculum served to increase students' conceptual

understanding of molecular concepts in biology relative to traditional biology labs and

activities.

Conceptual understanding was measured using pre and post unit concept maps

and post unit free response questions. This project did not use a control group;

comparisons were made between a non treatment unit that utilized only traditional, non

biotechnology methods and two treatment units that included specific biotechnology labs

along with traditional labs. The non treatment unit was the Cells unit and the two subsequent treatment units were Chemistry of Life and Molecular Genetics in a regular 10th grade biology class. Other factors that could contribute to differences in conceptual understanding gains between the non treatment and treatment units include the progressive learning dynamic that is imperative to classroom instruction; instruction was continuously adjusted to address students' misconceptions and to accommodate the diverse needs of all student participants. In addition, the proposed plan of labs did not occur as intended due to school wide scheduling issues such as state testing, advisement activities, and assemblies. For example, one biology class did not participate in the pGLO bacterial transformation lab and the GMO investigation lab occurred after the molecular genetics unit was complete. In my opinion, if all labs had been implemented according to the original plan, the case would be stronger for the inclusion of biotechnology labs into the high school science curriculum.
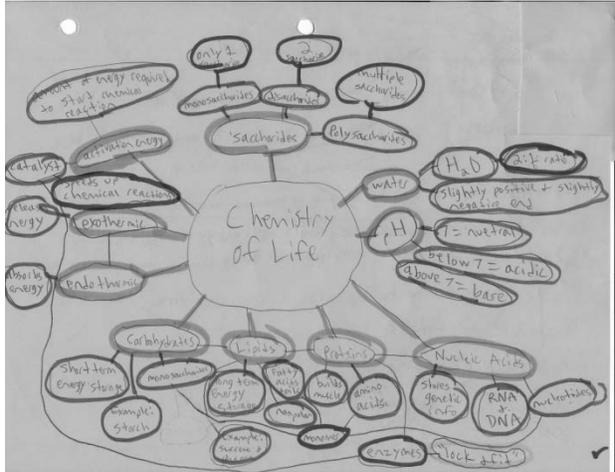
Concept Map Data

Concept maps were constructed by students as pre and post unit assessments to measure conceptual understanding. The maps were scored as described in the methodology section and using the concept map scoring rubric found in Appendix A. Below are examples of student concept maps that illustrate the ranges in conceptual understanding among students. In Figure 1, Samples from student "A" illustrate the difference in the amount of knowledge represented from pre to post concept maps.

Student A
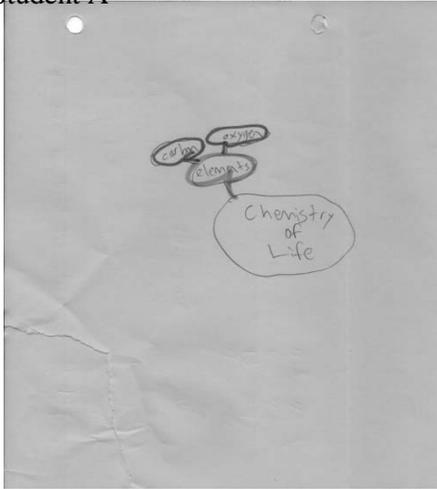
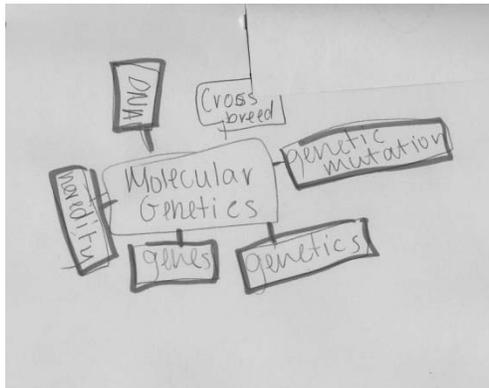Chemistry of Life Concept Map I
(Score = 16)
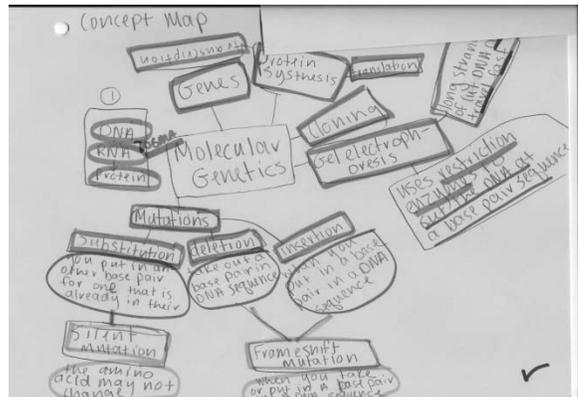
Chemistry of Life Concept Map II
(Score = 147)

Figure 1. Student A samples of Pre and Post Chemistry of Life Concept Maps.

Below in Figure 2 are samples from student "B" of pre and post concept maps for the

molecular genetics unit.

Student B

Molecular Genetics Concept Map I
(Score = 15)

Molecular Genetics Concept Map II
(Score = 106)

Figure 2. Student B Sample of Pre and Post Molecular Genetics Concept Maps.

After the concept maps were scored for individual students, the percent change

between concept map 1 (pre test) and concept map 2 (post test) was calculated for each

student. The average percent change was used to compare scores collectively by unit.

For the non-treatment cells unit, students' scores improved by 233 % overall, with a

mean difference of 65 (SD=38). In the chemistry of life treatment unit, students' scores

improved remarkably by 603 % overall, with a mean difference of 70 (SD=41). In the

molecular genetics second treatment unit, students scores improved by 359 % overall,

with a mean difference of 75 (SD=51).   Figure 3 below represents the percent change on

concept map scores by unit and demonstrates a higher percent gain in conceptual

understanding for the two biotechnology lab treatment units relative to the non-treatment
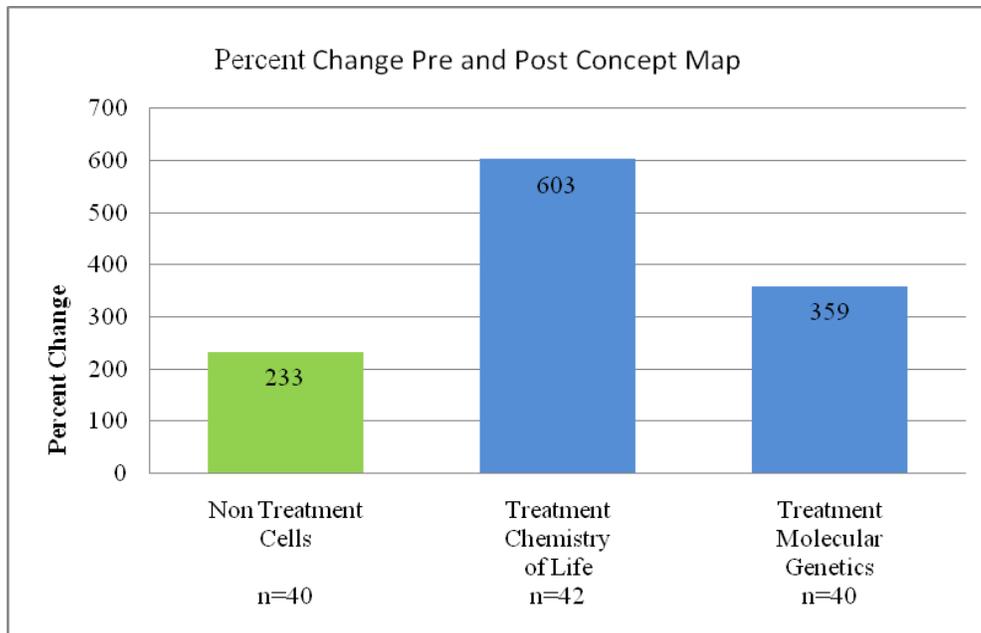
unit.

Figure 3. Percent Change on Pre and Post Concept Maps by Unit.

Free Response Question Data

        At the end of each unit as part of a unit test, students were directed to complete

free response questions to assess their ability to articulate conceptual understanding. A

complete itemization of all free response questions is found in Appendix B. The

responses of each question were evaluated separately and assigned a score: +2 for

significant knowledge; +1 for some relevant knowledge; 0 for no relevant knowledge;

and -1 for erroneous knowledge as described by Angelo & Cross (1993). Over all, when

the post test free response question scores were averaged by unit, a pattern of increasing

scores on conceptual understanding was revealed for the treatment units that included the

biotechnology labs and is represented in Figure 4 . The free response scores are compared

by non-treatment and treatment units; the non-treatment average score on free response

questions was 36 points and the treatment average score on free response questions was
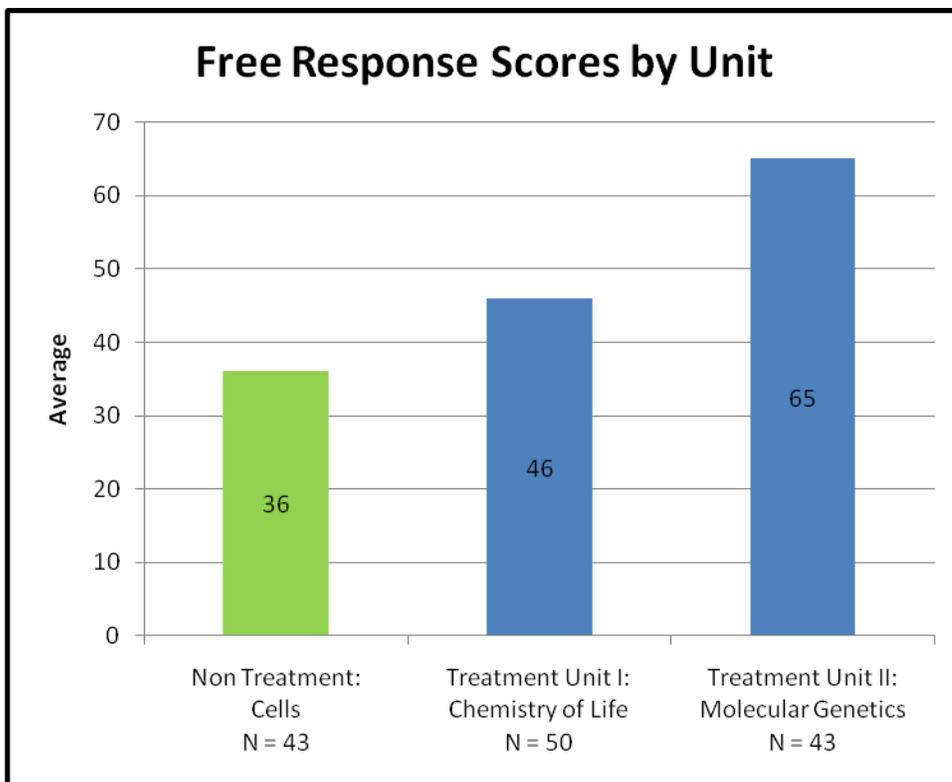
56 points, 20 points higher.

Figure 4. Post Test Free Response Questions by Unit.

In order to obtain a single score for each lesson topic for specific lab comparison

purposes, the percent of students representing "some knowledge" was added to twice the

percent of students representing "significant knowledge" and the percent of students

representing "erroneous knowledge" was subtracted for each topic. The scores are

represented in Figure 5. When topic questions were compared separately, the scores for

structure and function of DNA & RNA, structure and function of macromolecules, and

applications in biotechnology ranked highest for amount of articulated conceptual

understanding. These three highest scores are highlighted in blue in Figure 5 below and

are also three lessons that specifically included Bio-Rad and Vernier biotechnology labs

as part of the lesson.
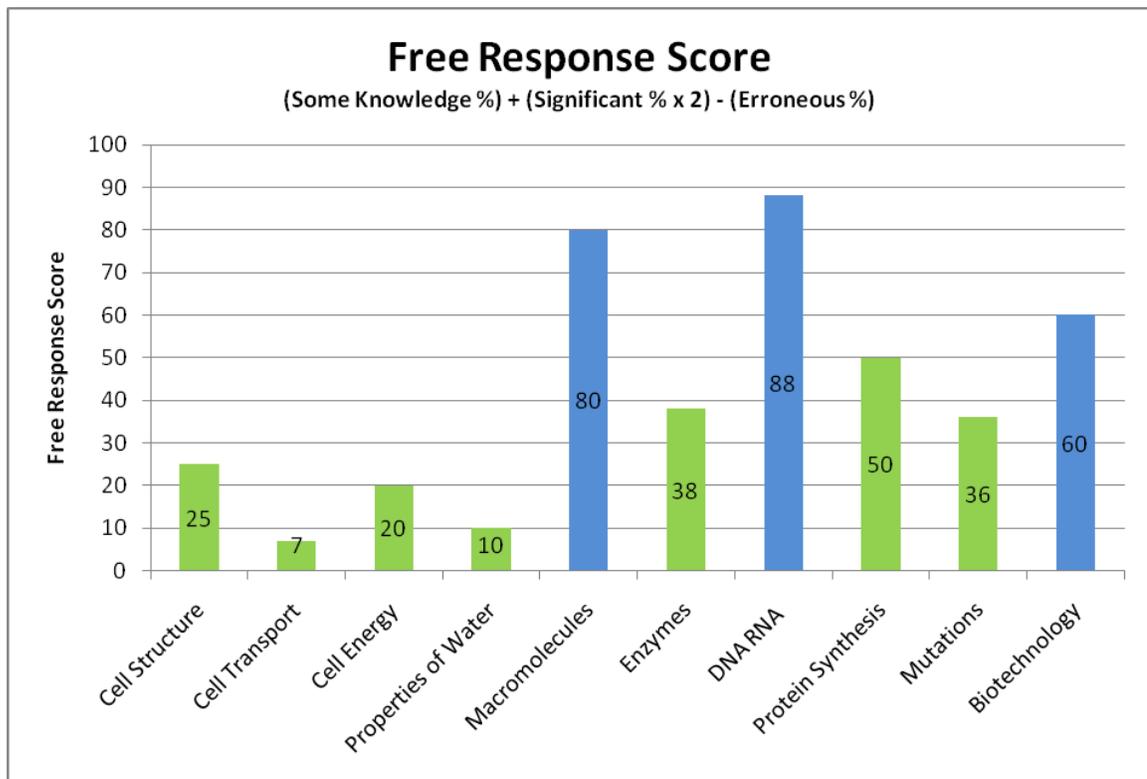
Figure 5. Student Conceptual Understanding by Topic as Assessed Using Free Response
Questions. Blue Represents Biotechnology Labs and Green Represents Traditional Labs.

Table 5 below, ranks the lesson topics by post test free response score as above and
identifies the lab type implemented as a direct part of the lesson as either biotechnology
lab or traditional lab experiences.

Table 5
Ranking of Lab Type by Post Test Free Response Question Score

Lesson Topic	Score	Lab Type	
DNA & RNA	88	Biotech	DNA Fingerprinting
Macromolecules	80	Biotech	Bradford Protein Assay
Biotechnology	60	Biotech	GMO Investigation
Protein Synthesis	50	Traditional	Paper Activity
Enzymes	38	Traditional	Starch / Amylase Lab
Mutations	36	Traditional	Card Activity
Cell Structure	25	Traditional	Microscope Lab
Cell Energy	20	Traditional	Photosynthesis Lab
Properties of Water	10	Traditional	Modeling and Demos
Cell Transport	7	Traditional	Osmosis in Eggs Lab

The lowest free response score was generated for the topic of cell transport and
the lab activity implemented was our department's traditional osmosis in eggs lab.
Students reported having fun with the "egg lab" and were observed to be highly engaged;
however many students could not explain how a concentration gradient in an
environment can drive the movement of water in and out of a cell, despite observing and
measuring gain and loss of mass in their eggs in different solutions. The egg and the
measurements were at a macro-scale, but students were expected to grasp the movement
of molecules through a membrane based on solute concentrations at the micro-scale. In
my opinion, the egg lab offers a demonstration to introduce osmosis, but does not really
address the complexity of cellular transport.

The highest score on post test free response questions occurred for the topic of
structure and function of DNA and RNA. The biotechnology lab implemented as a direct

part of the lesson was the Bio-Rad DNA Fingerprinting Lab. In the lab, students used

restriction enzymes to digest crime scene and suspect DNA, loaded DNA samples in gel

electrophoresis chambers, and analyzed the band patterns to find the most likely suspect

in the scenario. In addition, a paper modeling activity reinforced the molecular genetics

concepts related to the lab; thus illustrating the unseen molecular activity as a concrete

model. An important function of the DNA fingerprinting lab was the use of enzymes to

cut the DNA into fragments, thus providing an application for previous learning on

enzymes. This integration of multiple scientific topics is perhaps the greatest advantage

of the biotechnology labs; the students use the multiple concepts they learn to conduct

real, industry standard laboratory procedures which reinforces learning of complex

scientific concepts.

Student Interest in Science

The data related to the effect of biotechnology labs on students' interest in science

were obtained by using a pre and post attitude toward science survey, post lab mini

surveys, post lab interviews, and teacher observations. The results related to student

interest as a factor of attitude toward science were mixed and a clear relationship between

student interest in science and the inclusion of biotechnology in secondary biology

classes was not elucidated.

### Student Attitude Toward Science Surveys

A 20 statement Likert survey was implemented at the beginning of the fall

semester and again at the end of the semester. The specific statements related to the

attitude factor of interest were questions 14-20 on the Student Attitude toward Science

Survey (Appendix C). The survey statements were crafted in both positive and negative wording in order to minimize students uniformly checking boxes. When the surveys were tallied, the negatively worded statement responses were reversed. For example, statement #18 "I plan to take more science classes in high school even if they are not required for graduation." was a positive statement and a response of "strongly agree" was scored as "high interest" or 5. Statement #16 "I would like to spend less time in school studying science." was a negative statement and the Likert category was reversed; in that a "strongly agree" response by a student was scored as "no interest" or 1. In general, student interest in science slightly decreased as indicated on the survey results. The mean score on the pre-survey (n=50) was 3.66 (SD=0.38) and the mean score on the post-survey (n=44) was 3.36 (SD=0.36). Other factors noted in my observation journal, such as a poor student attitude in general at the time of the post treatment survey at the end of the course can account for the decrease in interest. A primary cause of the poor attitude was that our administration decided to require a multiple choice post test after students had already completed the state mandated end of course test; unfortunately the post test and the post treatment survey fell on the same day.

Post Lab Mini Survey Data and Interviews

Overall, the mean Likert score of student interest in biotechnology labs was slightly higher (3.82) than the mean Likert score of the non-biotechnology labs (3.78). The microscope lab, photosynthesis lab, the organic molecules lab, and the enzyme reaction lab were non-biotechnology labs. The protein assay lab, the DNA fingerprinting, and the GMO investigation labs were biotechnology labs.

Students completed mini surveys after each lab to gauge their attitude toward science in terms of interest, understanding, and usefulness of the lab activity. The mini survey questions can be found in Appendix D. Student Likert scores for the interest question were averaged to get a mean score for interest level of each lab. The survey score range was from 5 points for "extremely interesting" to 1 point for "completely boring". Figure 6 below tracks students' interest using the post lab mini surveys through a chronological sequence of labs. One claim could be that the protein assay lab and the DNA fingerprinting lab served to offer a pulse of increased interest as illustrated by the line representing student interest in Figure 6.
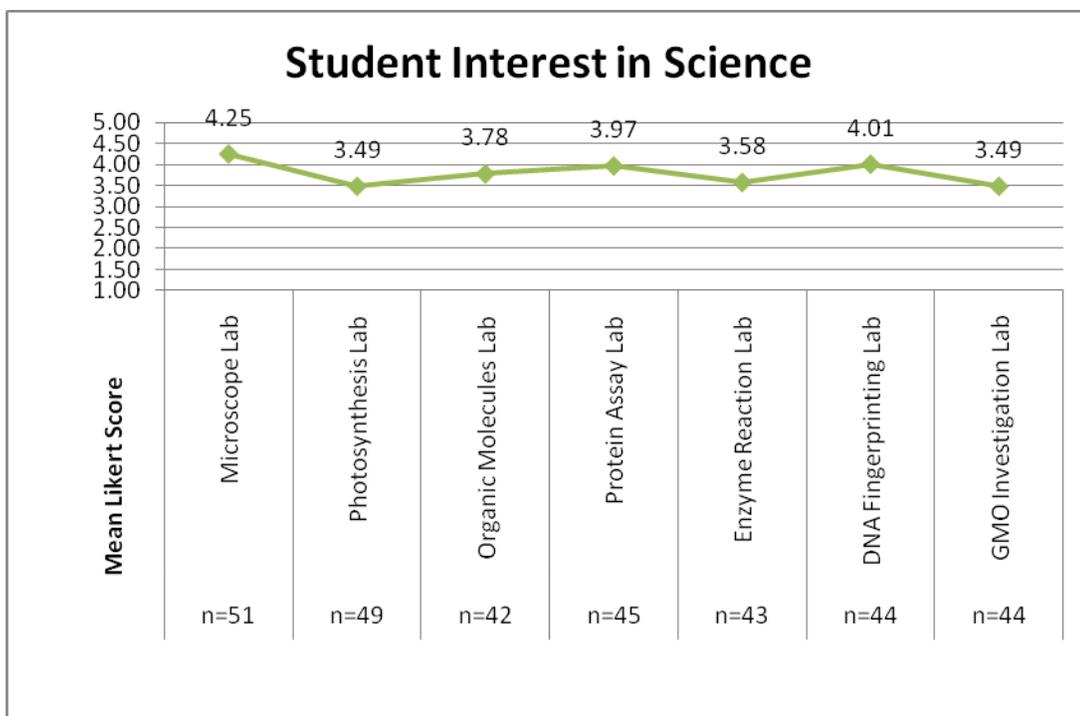
Figure 6. Levels of Student Interest in Science as Measured Using Post Lab Mini Surveys: 5=Extremely Interesting, 4=Interesting, 3=Slightly Interesting, 2=Slightly Boring, 1=Completely Boring.

When students were interviewed after the DNA fingerprinting lab in particular, they reported a high level of enthusiasm and most students indicated they enjoyed using

the equipment, loading the DNA into the gels, and watching the gel electrophoresis. The

most remarkable observation during the entire semester was the effect of the

biotechnology labs on two particular students that had failing grades and had outwardly

expressed contempt for biology. These two students were not only engaged during the

biotechnology labs, but they took leadership roles by training their peers to use the

micropipettors and to load the DNA into the gels for electrophoresis. The DNA

fingerprinting lab ranked the highest in terms of student favorites and most interesting of

all labs during the semester on the post lab surveys, interviews, and on the final course

survey.

<center>Student Confidence in Abilities to Do Science</center>

Quantitative data from surveys representing student attitude toward science did

not support the claim that biotechnology labs improve confidence in students' abilities in

science. However, qualitative data collected in the form of student interviews and

teacher observations support the continued inclusion and systematic study of

implementing biotechnology labs in secondary biology classroom of diverse ability

students when adequate support is also included.

Student Attitude Toward Science Surveys

As part of the same attitude toward science survey implemented at the beginning

and the end of the semester, students rated their confidence in scientific abilities. Survey

statements numbered 7 – 13 related to confidence as a factor of attitude toward science

and the student Likert scores were calculated in the same manner as for the interest

results. The results from the comparison of the pre treatment survey and the post

treatment survey indicate a decrease in reported levels of confidence in scientific

abilities. The mean score on the pre-survey (*n*=50) was 3.76 (SD=0.27) and the mean

score on the post-survey (*n*=44) was 3.54 (SD=0.26).

Post Lab Mini Surveys and Interviews

As part of post lab mini surveys, students rated their attitude toward science in

terms of confidence in understanding of the lab activity.   The overall trend in student

confidence in understanding decreased as the course progressed, except for the DNA

fingerprinting lab. Figure 7 tracks students' confidence using the post lab mini surveys

through a chronological sequence of labs.
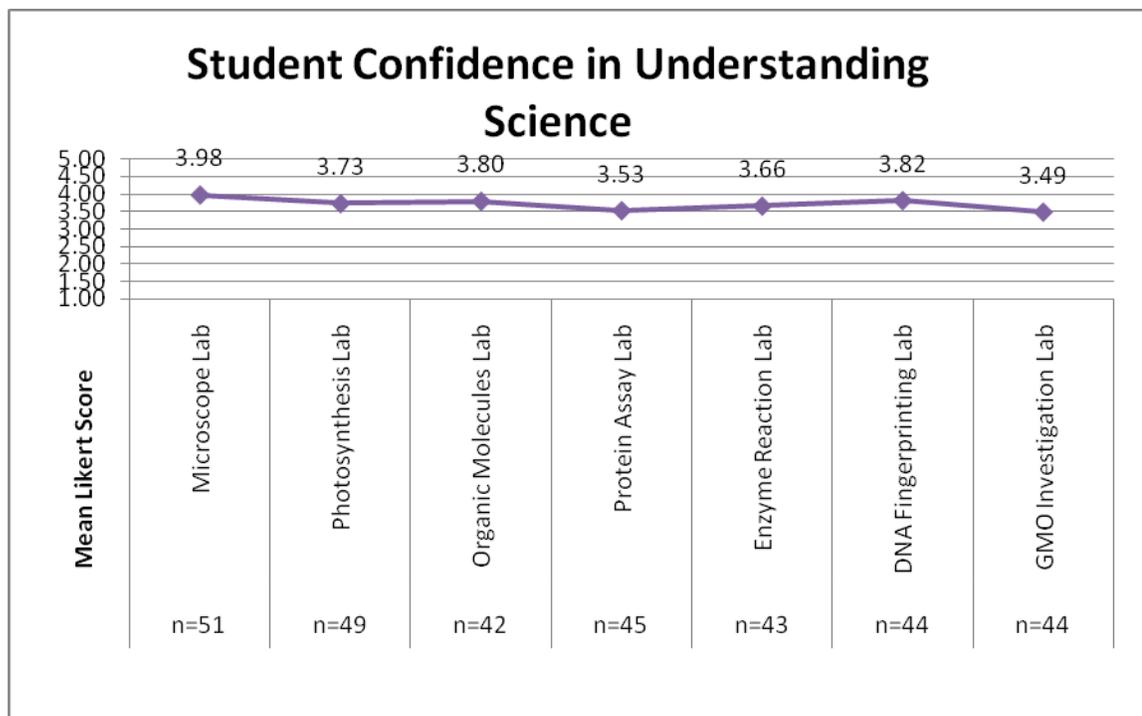
Figure 7. Levels of Student Confidence in Understanding as Measured by Post Lab Mini
Surveys: 5=Extremely Clear, 4=Clear, 3=Slightly Clear, 2=Slightly Unclear,
1=Completely Unclear.

The overall downward trend in confidence can perhaps be explained by the

increasing difficulty of the concepts. Immediately before the non-treatment cells unit,

students had completed an ecology unit and most students were proficient on the unit test

and therefore had a tremendously high confidence level to start with, as evidenced by the

pre attitude toward science survey. Initially high confidence could also be attributed to

the microscope lab implemented as part of the pre treatment cells unit, which is typically

a favorite as students spend three days observing and drawing live cells from pond water,

plants, and fungi. However, when the lessons move into increasingly difficult concepts

like cellular metabolism, chemistry of life and molecular genetics, students' confidence

typically degrades in a downward spiral. The photosynthesis lab, part of the non-

treatment unit, illustrates that the student confidence level decreased markedly. While the

directions for the photosynthesis labs were simple, post lab interviews revealed that

students did not feel confident about the purpose of the processes or their results and had

difficulty connecting their lab to the overall question of what factors affect the rate of

photosynthesis.

The Protein Assay lab, part of the treatment unit I also illustrates a relatively low

student confidence level. Despite Vernier lab instructions, we had great difficulty

generating a normal curve using standards for the unknown milk samples with the

Vernier colorimeter. We ended up having to compare the samples visually to roughly

quantify the protein amounts. The Bio-Rad student directions and analysis questions were

very difficult for students to interpret; thus leading to a decreased reported confidence

level on the post lab mini surveys. After the lab, all interviewed students vented

frustration with the instructions and the single colorimeter that had to be shared during

the lab. However, all students remarked and demonstrated a high level of engagement

during the lab and attributed their engagement to intrigue with the new equipment and supplies that they had never encountered before.

The purpose of implementing biotechnology labs as an intervention was to help students gain confidence in abilities to do science and in their understandings particularly when the science gets complex. Immersing students in biotechnology labs without scaffolding and support serves to decrease students' confidence in their scientific abilities. Lessons learned from the protein assay lab were used to adjust instruction before and during the DNA fingerprinting lab. As a result of the support, students reflected a relatively higher confidence level after the DNA fingerprinting lab on the post lab mini survey and during the post lab interviews. Due to time limitations to offer quality pre lab scaffolding and the even higher complexity of the GMO lab instructions and procedures, students' confidence in their abilities again decreased. Students that were interviewed after the GMO lab reported that they enjoyed grinding up their favorite snacks during the processing, but felt clueless about how PCR worked.

Effects of Biotechnology Labs on My Teaching Practice

Three important realizations during this capstone project have lead to changes in how I will implement biotechnology labs in the future: I will include pre lab strategies designed to enhance comprehensibility of complex processes like paper modeling activities, I will include enough time for small group debriefing at the analysis stage of a lab, and I will allow students to participate fully in all aspects of a lab, including the prep work.

The overwhelming message I gleaned from surveys, interviews, and observations was that labs promote interest and confidence when the concepts are understandable. If students understood the primary procedures and concepts of a lab and found the lab interesting, they reported that they "liked the lab" and "it was fun". The comments that students made about the DNA fingerprinting lab indicated that the lab was "awesome" and "fun" because the lab was similar to real laboratory procedures, but also that they understood the lab better. The support for concept development of DNA fingerprinting occurred with a paper activity that modeled restriction enzyme digest and separation of DNA fragments by electrophoresis ("Who Broke the Rule? No Electronics at School!" Georgia Department of Education). Equally important, students reported that they understood the process of DNA fingerprinting more fully after analyzing their gels. In order to analyze the gels, I had lab groups rotate to a "consultation" area where students put their gel on the overhead for optimal analysis of band patterns and I modeled how to precisely measure the distance between bands and how to compare banding patterns of the samples. I observed students' process skills with this task and encouraged questions. A big part of the discussion involved sources of error and how the results were affected. When mistakes were realized, students had to think critically and a livelier discussion resulted. Many students commented that they would like all labs to be completed in this manner. Sitting down with a lab group at the analysis stage is more powerful at facilitating conceptual understanding and building confidence in abilities to do science than walking by and stopping briefly during lab activities and whole class discussion of general results.

Unfortunately, the bacterial transformation lab and the GMO investigation labs occurred at a time in the semester when state mandated end of course testing was approaching; therefore time was limited. While the students were engaged in these labs, the same high level of support at the analysis stage was not given and students did not feel they understood the concepts related to the lab, despite students reacting with amazement at the end of the lab when viewing their incubated Petri dishes of bacterial colonies that fluoresced green. The GMO investigation lab also engaged students at a high level during the procedures, but a lack of time to analyze the results lead to confusion for most students. Very few students represented information on concept maps, free response questions, or surveys related to the processes of gene transfer or PCR. Bio-Rad kit instructions and analysis questions were difficult for students to follow and to understand. For successful implementation of biotechnology labs in the future, these procedures and analysis questions would need to be re-written for comprehensibility support.

INTERPRETATION AND CONCLUSION

Integrating Biotechnology into Secondary Education

Biotechnology labs offer powerful applications of molecular biological concepts when appropriately implemented. Besides time for the lab, sufficient time must be planned for scaffolding activities that model the processes like restriction enzyme digestion, separation of DNA fragments by size, or polymerase chain reaction so students understand the mechanisms of the processes. Sufficient time must also be planned for

small group instruction at the analysis stage so students are able to discuss results and

possible sources of error. Without sufficient time for the pre and post lab support, we are

merely offering very expensive, however fun, sources of confusion for our students.

With the supports, biotechnology labs integrated into the secondary biology curriculum

can enhance conceptual understanding and motivate students to persist in a scientific

pathway. Many students expressed an interest in taking a biotechnology class if the class

were offered.

An important understanding about my students that I gained was that students

want to be fully involved in the preparation of the biotechnology labs. Students were

very curious about how the electrophoresis gels were made and how the nutrient media

for the bacterial transformation was prepared. When I told them how I spent the previous

evening making media and pouring plates for the pGLO lab, several students expressed a

desire to be able to learn about all of the procedures. I prepared as much as possible

before the labs to save time, but the result was essentially cheating my students from fully

participating in the lab. Preparing solutions and media are as much of the science as the

flashy techniques like the gel electrophoresis and PCR. Is it possible, for students to fully

understand PCR when they put their samples in a machine that is already programmed?

Perhaps the first PCR lab should be done the original way with water baths and manual

transfer of the sample to different temperatures? No wonder students were unsure about

PCR; they were only participating minimally in the procedures. Offering a

biotechnology course, or ideally a biotechnology pathway as a collaboration between our

science department and our vocational education department will allow students to fully

engage in skill development necessary for beginning a career in the biotechnology

industry.

VALUE

Biotechnology labs, like DNA fingerprinting can and should be implemented as

part of the high school biology curriculum. The result of implementing biotechnology

labs in a regular level high school biology class and systematically assessing student

conceptual understanding and attitude toward science leads me to the further conclusion

that a biotechnology class should be offered at the high school level to introduce students

to the full experience of biotechnology skills, equipment use, concepts, and career

options. In addition, a biotechnology pathway, as described by the Georgia Department

of Education will successfully prepare our students in Tift County, Georgia to become

part of a highly skilled workforce in the growing biotechnology industry.

Biotechnology is a high growth industry at global, national, and state levels

despite the recent economic downturn. The average wage for a bioscience job is $77,595

annually, which is well above than the U.S. average annual wage (Biotechnology

Industry Organization, 2010). There are four main areas of biotechnology industry

growth: Medical/Pharmaceutical, Agricultural/Biofuel, Industrial/Environmental, and

Diagnostic/Research (Daughtery, 2007). Within these areas are a wide variety of fields

and education level requirements for students to consider as they prepare for their future

careers. For students to prepare for careers in the high growth biotechnology sector, they

will require early opportunities to gain the skills necessary for entry level biotech jobs

and internships.

In Georgia, science test scores are not a favorable indicator of readiness for growth in the bioscience sector. Relative to other states, science achievement ranks between 28th to 41st on science AP, ACT, and NAEP assessments (Battelle, 2009). Therefore, Georgia will not lead in attracting biotechnology industry or lead in preparing students for careers in biotechnology fields unless innovative changes are made in the high school curriculum. My capstone project with regular high school biology students helps to support claims that the applied and integrated nature of biotechnology experiences will improve conceptual understanding of scientific concepts (Wetherington, 2010). Georgia has a multitude of programs in place to support STEM education, specifically for the integration of biotechnology curriculum to enhance the development of a highly trained workforce. Two programs that supported this project are Georgia Bio and National Environmentally Sound Production Agriculture Laboratory (NESPAL). If our community places a high value on attracting business in the biotechnology sector, then a high emphasis should be placed on preparing our students to enter the biotechnology workforce. Biotechnology professional development, newly developed biotechnology state curriculum, and grant funding for equipment and supplies are available to support inclusion of biotechnology instruction in high school science education now. Initiating biotechnology labs in the high school biology curriculum and building a biotechnology pathway will begin to meet the demand for a highly trained workforce necessary for economic growth in Tift County.

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APPENDICES

APPENDIX A

CONCEPT MAP SCORING RUBRIC

Appendix A
Concept Map Scoring Rubric

Map 1: Concept Map Components	Value	Number	Points Earned
Concept Labels	1 x		=
Relationships	1 x		=
Branching: Each additional link	3 x		=
Hierarchies	5 x		=
Crosslinks	10 x		=
		Total Points:	
Alternative Conceptions Present:			

Map 2: Concept Map Components	Value	Number	Points Earned
Concept Labels	1 x		=
Relationships	1 x		=
Branching: Each additional link	3 x		=
Hierarchies	5 x		=
Crosslinks	10 x		=
		Total Points:	
Alternative Conceptions Present:			

Map 2 Score: _____ **-** Map 1 Score: _____ = Overall Conceptual change Score: _____

APPENDIX B

POST TEST FREE RESPONSE QUESTIONS

Appendix B

Post Test Free Response Questions

Pre Treatment Unit: Cells

1. Between which cell types is the difference greater – plant and animal cells or between prokaryotic and eukaryotic cells? Give reasons for your answer.

2. What structures are contained in eukaryotic cells that are not present in prokaryotic cells? What is the function of each of these structures?

3. What problems might a cell develop if its plasma membrane did not have selective permeability? Explain.

4. Use your knowledge of osmosis to explain what happens when a plant wilts.

5. Compare and contrast the processes of photosynthesis and cellular respiration.

Treatment Unit I: Chemistry of Life

1. Why is water essential to life? Describe four or more properties of water and relate each property to explain the impact of water on living organisms.

2. What are the macromolecules that make up living organisms? List the four types, describe the general structure and function of each, and give one example of each type.

3. Why are enzymes important to living organisms? How do enzymes function as catalysts in metabolic reactions? Give an example of one enzyme and its substrate.

Treatment Unit II: Molecular Genetics

1. Compare and contrast the structure and function of DNA and RNA. Identify a nucleotide and label all parts of the molecule in the figure.

2. How do genes code for biological traits?

3. What are genetic mutations and how are they caused?

4. What is biotechnology and what role can it play in the future related to genetics? Explain examples.

APPENDIX C

STUDENT ATTITUDE TOWARD SCIENCE SURVEY

Appendix C
Student Attitude toward Science Survey

Directions: Read each statement carefully. Use the scale below to indicate how much you agree or disagree with each statement. Record your answer on the line next to the number of each statement. This survey is anonymous; please, do not put your name on the survey.

A Strongly agree	B agree	C neutral	D disagree	E Strongly disagree

_____ 1. Science is useful for the everyday problems in life.
_____2. Most people should study some science.
_____ 3. It is important to know science in order to get a good job.
_____ 4. You can get along perfectly well in everyday life without science.
_____ 5. Most of the ideas in science are not very useful.
_____ 6. I will need to understand some science for my future career.
_____ 7. I am good at working science labs and hands-on activities.
_____ 8. I remember most of the things I learn in science classes.
_____ 9. I have a good feeling toward science.
_____ 10. If I do not see how to do a science assignment right away, I give up.
_____ 11. It makes me nervous to have to take a science class.
_____ 12. I feel I could handle advanced science courses.
_____ 13. I can get good grades in science.
_____ 14. Sometimes I read ahead in my science book.
_____ 15. Doing science labs or hands-on activities is fun.
_____ 16. I would like to spend less time in school studying science.
_____ 17. I can see myself working in a science related career.
_____ 18. I plan to take more science classes in high school, even if they are not
              required for graduation.
_____ 19. I would like a job that does not use any science.
_____ 20. I enjoy watching a science program on television.

APPENDIX D

POST LAB STUDENT MINI SURVEY AND LESSON FEEDBACK

Appendix D
Post Lab Mini Survey and Lesson Feedback

Date: _____   Lesson: _____

Directions: Please respond honestly to the questions below by **circling** the answer that you agree with the most.

1. On the scale below, rate how well you *understood* the lesson today.

Completely Unclear	Slightly Unclear	Slightly Clear	Clear	Extremely Clear

Describe what was unclear or confusing:
_____

2. On the scale below, rate how *interesting* you found the lesson to be.

Completely Boring	Slightly Boring	Slightly Interesting	Interesting	Extremely Interesting

Suggest what you think would have made today's lesson more interesting to you.
_____

3. On the scale below, rate how *useful* today's activity was in helping you learn the lesson.

Completely Useless	Slightly Useless	Slightly Useful	Useful	Extremely Useful

Tell me how I can help you improve your learning in biology.
_____

APPENDIX E

STUDENT INTERVIEW QUESTIONS

Appendix E
Student Interview Questions

Treatment Unit 2: Molecular Genetics – DNA Fingerprinting Lab

1. Tell me about what you learned related to Molecular Genetics (DNA)?

2. What did you learn about Biotechnology (tools and methods used in the lab)?

3. What part of the DNA fingerprinting Lab did you like the most?

4. Was there a time during the lab activity that you did not feel confident?

5. What suggestions would you give me to make lab experiences more meaningful

    to you?

APPENDIX F

DAILY TEACHER REFLECTION

Appendix F
Daily Teacher Reflection

Date: Unit: Special Circumstances:	
Goal of Lesson:	
Lesson Outcome: (What do I know students learned today?)	
Reflection	
What went well?	
What did not go well?	
How did the student respond?	
What are my goals for this class tomorrow?	
What would I change about this lesson?	

APPENDIX G

BIOLOGY ACQUISITION LESSON PLAN

Appendix G
Biology Acquisition Lesson Plan

Topic: Structure and Function of DNA

Essential Question: What is the structure and function of DNA? Time Required: Five 90 minute blocks
GPS Addressed: SB2. Students will analyze how biological traits are passed on to successive generations. SB2 a. Distinguish between DNA and RNA.
Activating Strategy: Part I: Alternative conception identification: Students respond to anonymous genetics probe questions. 1. How are biological traits determined? 2. What is a gene? 3. What are genetic mutations and how are they caused? 4. What is genetic engineering and what role can it play in the future? Part II: Review of the macromolecules and nucleic acids. Students use textbook to identify components of nucleotides of DNA. Students use materials to represent each component to build a 3D model of DNA. (Can use art supplies, food, or DNA modeling kits).
Vocabulary to preview: Genome   Nitrogen bases Nucleotide   Adenine Base pairs   Guanine Complementary strand   Cytosine Replication fork   Thymine DNA polymerase   Anti-parallel orientation
Assessment Prompts Instructional Strategy: Students are given handouts with the molecular representation of DNA. Using the textbook illustration as a guide, students circle with a colored pencil, each phosphate, then each deoxyribose group, and then each nucleotide (adenine, guanine, cytosine, and thymine) using a key. Student then cut out all the nucleotides into separate manipulatives. Assessment Prompt #1 Students will accurately build a 2-D sequence representing the structure of DNA using nucleotides and demonstrating correct base-pairing rules.

Instructional strategy: Question is posed, How can DNA be copied so that there are two identical sets of DNA before cellular division? Students in groups experiment and explain their hypotheses. Evaluate each group's theory as a whole class for feasibility and alternative conceptions. Model the scientifically accepted semi-conservative model of DNA replication.

Assessment Prompt #2 Students will demonstrate the process of DNA replication using nucleotide manipulatives.

Summarizing Strategy:
Introduce technical vocabulary of DNA replication (Enzymes helicase and polymerase, template, anti-parallel orientation, . Students discuss and model the sequence of events in DNA replication.
Assessment Prompt #3 Students write a sentence for each major step in DNA replication using technical vocabulary in a graphic organizer to summarize the process.
Examples:
Semi-Conservative Model of DNA Replication
1. DNA is "unzipped" by the enzyme DNA helicase.
2. The unzipped strands serve as templates for nucleotides to attach.
3. Nucleotides are added using base-pairing rules and by the enzyme DNA polymerase.
4. The two copies of DNA each have one old strand and one new strand; this is called the semi-conservative model of DNA replication.

Biotechnology Lab Activities:

Activity One: Students work in pairs to complete Internet Activity DNA Extraction and Gel Electrophoresis Simulation found at http://learn.genetics.utah.edu/units/biotech/

Activity Two: Students work in pairs to complete Georgia DOE performance task "No Electronics at School! Who Broke the Rule?" found at
https://www.georgiastandards.org/Frameworks/GSO%20Frameworks/9-12%20Biology%20Biotechnology%20Task%20Gel%20Electrophoresis.pdf

Activity Three: Students work in groups of four to complete Pre-Lab Introduction and Restriction Digestion of DNA Samples (Bio Rad Forensic DNA Fingerprinting Lab Part I). Samples will be incubated and then allowed to reach room temperature slowly overnight.

Activity Four: Students work in groups of four to complete Agarose Gel Electrophoresis (Bio Rad Forensic DNA Fingerprinting Lab Part II). Gels will stain overnight and be analyzed the following day.

Assessment: Performance assessment and analysis questions for each activity

Extension for Gifted Students: Quantitative Analysis of DNA Fragment Sizes by constructing a standard curve.