Authentic Classroom Collaborative Research as a Scaffolding Tool to Independent Research

Retaining and Preparing Students for A Capstone Research Course in Biotechnology

Kathryn Kehoe

Teacher of Biotechnology
Academy of Biotechnology and Medical Research
Ponte Vedra High School
460 Davis Park Road
Ponte Vedra, FL 32081
kehoek@stjohns.k12.fl.us

Abstract: This proposal examined student attitudes and interest for independent scientific study as a result of authentic collaborative research on genes linked to a human trait or disease. Student research used web based bioinformatic tools. The students in this study were enrolled in the third course of a four-year curriculum in a career academy focusing on biotechnology and medical research. Biotechnology III is project based, with some components relying on standard activities that cannot be considered authentic research. However, the goal of the course is to prepare students for original projects. The intervention, using genetic data bases, provided students with research skills necessary for the selection of a topic and a direction of study for the fourth year. The student selected topic should have been conducive to realistic scientific inquiry as part of the independent research course offered in the fourth year.

Rationale: Ponte Vedra High School (PVHS) in St Johns County, FL had its inaugural year in 2008 with 48 students enrolled in the Academy of Biotechnology and Medical Research. During the 2010-11 school year, 32 of the original 48 students returned to enroll in Biotechnology III. Due to scheduling conflicts, eleven of the 32 students were unable to meet during the set class period and were scheduled in Biotech III during a school period that fit their schedule. Working independently, each student had the option of serving as a teacher assistant or performing research, (an option also given to seniors in the regular class). Only three students elected to engage in scientific inquiry. The focus of the academy is to teach skills, concepts and awareness of careers in the biotech industry, with the emphasis on basic research. Only 21% of the students who were eligible for the research option selected this.

Biotechnology III provides the necessary final course in the three course sequence required of a career academy curriculum. Fourteen of the eighteen juniors returned to biotech for a fourth year in an honors level research class (five students completed the program at three years and did not elect to have Biotech on their senior schedule). Of these 14 rising seniors, only one student had a well defined research project prior to the start of the school year. While the remaining students went on to define and perform their projects, the student who started the year with a predetermined project was by far the most successful, winning the local science fair, placing second at the state level and then representing his school at the Intel Science and Engineering Fair.

The goal of this intervention was to introduce into Biotechnology III, a unit that provides a student focus on selection of an authentic research topic by the end of the course. The assumption tested was that students who have a sense of ownership and responsibility for a project will be more likely to return for the 4th year as a developing science “professional” capable of authentic research and thus, this intervention also served as a device to reduce attrition from the program.

The proposal was guided by the following objectives.

1. Students will gravitate from a preference for highly procedural, teacher-centered approach with prescribed outcomes (approximately 80% of the students in 2011) and develop their own independent, open ended investigations.

2. Students will develop skills for using genomic data bases important to biotechnology, using this as an authentic scientific tool for individualized research.

3. Students in Biotechnology III will have developed the framework for an empirical investigational project by the end of the first semester.

4. Increased retention of students to the fourth year research course.

The biotechnology curriculum that has been developed at PVHS focuses heavily on skill and concept acquisition. Biotech I students are immersed in DNA based studies that make use of their own genomic sequences to study broader topics related to genography, population and Mendelian genetics, and genetic fingerprinting. They learn the details of the polymerase chain reaction (PCR) and also how to glean basic information about DNA and genes from the National Center for Biotechnology Information (NCBI) website. The study shifts to proteins and genetic cloning in the second year. Biotechnology III, first introduced in 2010-11, utilizes model organisms in a project based approach. However, the projects are educational in nature and do not represent empirically investigative inquiry.

Student presentation at mini-symposium

It has been argued by the American Association for the advancement of Science and the National Research Council, this is not the direction in which K-12 science education should proceed, but instead the emphasis should be to “engage students in authentic, long-term science investigations” (Hsu, 2009). Indeed, when students have been engaged in courses in which the focus is student driven research, students have shown mastery of both skills and concepts, while also developing the ability to formulate questions and think critically (O’Neill, 2004). This approach often argues for building greater understanding of how science operates. American education has often been criticized as being, ‘‘a mile wide and an inch deep’’ (Vogel, 1996) which means students fail to develop a thorough understanding of a topic and instead “learn just a little about an enormous range of topics.” This, described as a survey approach to science, is provided as a basis for reduced academic achievement in the United States relative to other countries (O'Neill, 2004). By engaging research projects there may be less content covered, but students would "build a deeper understanding of how scientific knowledge claims and theories are constructed" (O'Neill, 2004). These are the goals for students in the PVHS biotechnology program, especially as they pursue studies in science beyond the secondary school.

To launch students into the research arena, students were engaged in authentic research using the human genome data-bases. It has been shown that when students develop their own incentive for research (their choice of a gene associated with a human trait or disease) and the activity combines an exploratory project combining computer database research with lab experimentation, there is substantial increase in motivation and curiosity. (Kirk,2006)

It is becoming increasingly important that students in the 21st century understand the function of computers in processing large amounts of information in medicine and science (Wefer, 2003). While students had experience with the use of the NCBI website from the first course, the goal of revisiting this tool in Biotech III was to provide students with an opportunity to use additional aspects of the site and other web-based resources in empirical scientific research. Previous work was more along the lines of a series of point-and click actions in which the emphasis was on ''correct'' answers. Those activities were a linear, teacher-centered, planned ''lab'' or activity; an approach which severely limits the potential for scientific inquiry by students (Waight, 2008). In defense, previous studies provided a launching point by which students would be able to begin their own inquires and the potential for exploration of the scientific topics surrounding the DNA responsible for genetic diseases and traits. Research has shown that to fully master the content, bioinformatics requires an interaction between two domains consisting of a knowledge set and skill. (Wefer, 2008) Students may not have acquired the background "concrete knowledge (e.g. genetics) that was needed to understand bioinformatics applications" (Wefer, 2008) the first time around.

Student presentation at mini-symposium

And of course, the ultimate goal of this intervention was to help students learn to think and work independently, taking responsibility for their own learning. (Hunter, 2007) With a vested interest and ownership of a project and its progress, the outcome should be greater student retention for the capstone research course.

Action Research Intervention: The goal for this activity was to help 3rd year students develop skills of novice researchers. Students selected a human trait or disease to study using information on the NCBI and commercial websites. The multi-week project (one defined task per week) had students research all aspects of the genetics of a trait/gene and also design a PCR assay to identify the locus of personal interest in their own genome. Ultimately each student created a professional scientific poster presented at a mini symposium at the conclusion of the unit. A similar project was assigned to University of Florida undergraduates in a genetics course as presented at the Bench to Bedside summer institute 2011 by Mr. Rolando Garcia-Milian. Mr. Milian's instructions and worksheet provided information for the initial lesson.

Assistance for the selection of topics of interest was provided through "Disease Wednesday" lectures, a popular tradition of the Biotechnology Academy in which students are exposed to representative genetic disorders. Allowing Biotechnology III students to select a topic of interest, provided a personal stake in the research information gained. Typically students in courses using this approach to study genomic data basis report that the "personalization of their genomic trek in the choice of topic and use of their own DNA substantially" increased their motivation and curiosity for independent research (Kirk, 2006). This activity encouraged scientific literacy and provides students with an" opportunity to appreciate the power of the internet and computers in scientific research" (Wefer, 2003).

Students who selected similar traits/genes were organized into groups to work together on the research. Students came to know the challenges and rewards of deriving information from the human genome project. Since aspects of a gene or trait may not be known, some students faced difficulty in finding important details. It has been suggested "that struggling (and even failing) to formulate and carry out empirical investigations in science may teach students more meaningful lessons about how science is accomplished than flawlessly executing cookbook labs or solving carefully formulated problems" (O'Neill, 2004). Ultimately, homologous forms of the gene were identified in *C. elegans*, and the information prepared to use in a PCR assay to generate the DNA necessary to create a feeding vector to perform RNAi, a project undertaken by students during the 2nd quarter.

Phenotype	*Gene*	*Notes*	*Reference*
Coat color in dogs	RSPO2 F6F5 KRT71	R-spondin2 Fibroblast growth factor-5 Keratin-71	www.science mag.org/cgi/content/abstract/1177808
Intellectual impairment	Fragile X	Drug (mGluR5) block overactive receptors that play a key role in weakened synapses	Randi Hagerman at U CA Davis Stephen Warren at EMory
Malignant melanoma	BRAF	**B-Raf proto-oncogene serine/threonine-protein kinase** The B-RAF protein is involved in sending signals in cells and in cell growth This protein plays a role in regulating the MAP kinase / ERKs signaling pathway, which affects cell division, differentiation, and secretion	http://www.sciencecodex.com/trial_of_new_treatment_for_advanced_melanoma_shows_rapid_shrinking_of_tumors Drug PLX4032 blocks the faulty gene
Breast Cancer	HER-2+ mutation	HER 2 = human epidermal growth factor receptor 2 AKA = ErbB2 proto-oncogene encodes a receptor tyrosine kinase, which is frequently amplified and overexpressed in human tumors. Tumors overproducing HER-2 are good candidates for the drug Herceptin which cuts chance of cancer recurrence nearly in half	http://www.mayoclinic.com/health/breast-cancer/AN00495 http://www.pnas.org/content/99/13/8880.full Personalized medicine see 1000 genome project (sequence the genomes of 1000 people to produce a catalog of all genetic variations that exist in the 1% of human population....simplified by sequencing only the exome (the 1% that codes for genes)
Tanning response	MCR-1 3 variants	Melanocortin-1 receptor A person's ability to tan is influenced by variants of this gene 3 Variants R151C R160W D284H block the transformation of pigment molecules --people w/1=moderate tan, 2=red hair freckles, burn	www.genomenewnetwork.org/articles/10_00/melanoma_risks.html Am J Hum Genet 67 (Oct 2000)

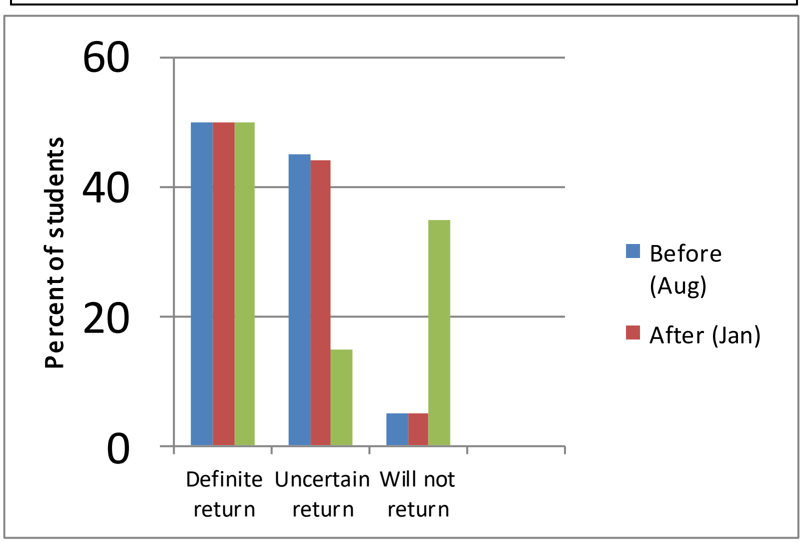
Fig. 1 Examples of Gene Choices Given to Student to Assist Choice.

Connections to Bench to Bedside summer institute: The description of the student presentation of a "professional" scientific poster using information from the NCBI website by Mr. Garcia-Milian, immediately brought to mind the worthiness of this activity for students in Biotechnology lll. Mr. Garcia- Milian provided instructional information and a practice activity to launch students into NCBI BLAST use. Also students were encouraged to develop authentic research based on the research topic they presented. While students in the biotechnology at PVHS were familiar with both the use of bioinformatic web based tools and techniques of PCR used in the study, it was noted by more than one reference that implementation of these skills in the secondary classroom “were limited to teachers with high levels of proficiency and access to the associated technologies,” and that “researchers often have identified teachers as the ‘‘weak link’’ in efforts aimed at technological adoption. Time and again, they have called for more teacher training, more classroom support for teachers, and more curriculum scaffolding” (Waight, 2008) In order to encourage more practice-based scientific literacy the pre-colligate classroom teachers need to adopt pedagogy focusing more on research studies. It was noted that this would require a large, long-term investment in teacher professional development (O’Neill, 2004) as was provided, in some measure, by the two week summer institute.

Data Collection and Analysis: Students were given a pre-test and post-test (see appendix) to determine knowledge of internet based tools. Students were asked to complete pre- and post-activity questionnaires to assess interest and attitudes towards authentic student research. The percentage of students that continue to the 4th year research course and elect to perform inquiry projects were compared to pre-intervention numbers. Qualitative measures of competency were noted in student posters, lab notebooks and teacher observations. The mini-symposium was photo-documented.

Results: Twenty students were questioned about their interest in returning to biotechnology for a fourth year in which students will be required to perform independent research and with an obligation to enter into a science fair. At the beginning of the year, nearly 50% of the students indicated their intentions of returning, while only 6% had already made the decision not to return (Fig 2) . The remainder of the students were undecided. By the end of this study (which corresponds pre-registration) the majority of the undecided students had made the decision to not return to Biotechnology. The most common reason why they chose not to return was because of a perceived difficult senior year with no time for a biotech project, or a desire to have an easy senior year. One student did indicate as one reason, the inability to select a research project.

Figure 2. Student response to a return survey to 4th year



Those students who did select to return to the 4th year, greater than 40% did have a project in mind, This was a great increase over the first of the year in which no students indicated a potential project was planned. The numbers with "no idea" had fallen to the lowest number. (Figure 3)

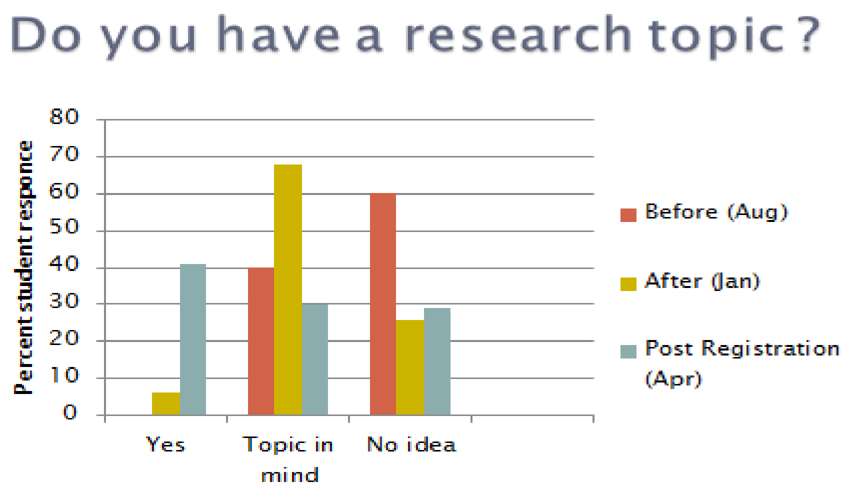


Figure 3. Students response to selection of research topic. Students were surveyed at the beginning of school, at the end of the 1st semester and then again post-senior year registration

What factors assisted with these decision? Students indicated that several factors contributed to the development of a project with the gene project figuring prominently in the selection of a project. (figure 4). Other class topics also provided a basis for selecting an idea.

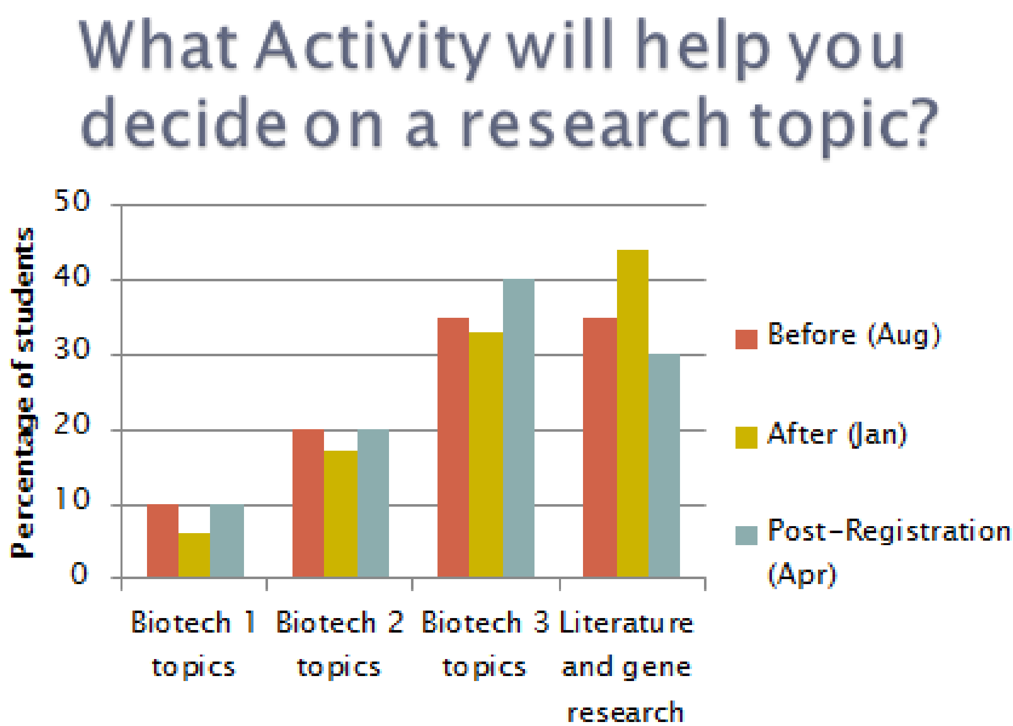
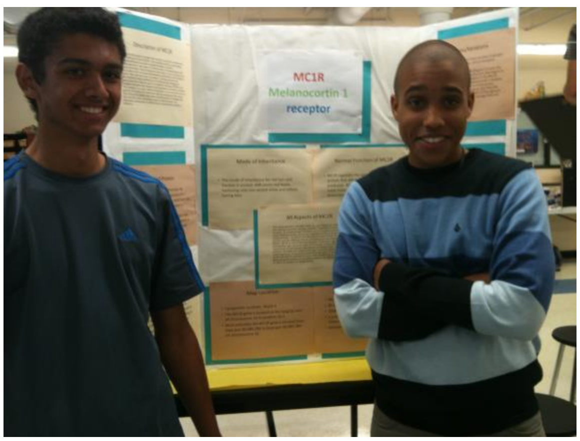


Fig. 4 Students response to method of selection of research topic. Students were surveyed at the beginning of school, at the end of the 1st semester and then again post-senior year registration.

Conclusions:

While the activities presented in Biotechnology III included the development of skills using genomic data bases important to biotechnology, and using this as an authentic scientific tool for individualized research, it was not cited by a majority of students as the way their potential project was formalized. Skills learned and activities experienced in class activities other than the gene project also contributed to the choice being made by the student. Several students did develop the framework for an empirical investigational project by the end of the first semester; one of the goals of the project. The last objective was to improve retention in the 4^{th} year course. In 2010-2011, 72% of the students returned for a 4^{th} year. After this intervention, the number remains close to the same (70%). Student not returning appeared to already suffer from “senioritis” in that they did not want the challenge of independent research. One did select the option of stating they would not return because they did not have a topic for a research project.

Beyond the objectives and results of the project, the activities used in the course were beneficial to the students and will be continued as unit in the course.



Appendix:

Survey: Student Attitudes towards Biotechnology III

Please **DO NOT** place your name on this survey. There will be no attempt to place your responses with a name. Pleased answer as honestly as possible.

a b c d

O O O O 1. Are you taking Biotechnology III because you want to, or because you have to?

a. I want to take biotech

b. I have to take biotech because_________________________________

____

O O O O 2. What activities in Biotechnology do you like the best?

a. Lectures, including Disease Wednesday and Breakfast with biotech

b. Lab activities that follow a planned protocol

c. Lab activities that are open-ended (recall the food testing lab in Biotech II)

d. Working in groups on assignments and projects not necessarily in the lab—computer based, reading articles, creating posters, etc.

O O O O 3. What activities in Biotechnology do you like the second best?

a. Lectures, including Disease Wednesday, Breakfast with biotech

b. Lab activities that follow a planned protocol

c. Lab activities that are open-ended (recall or food testing lab in Biotech II)

d. Working in groups on assignments and projects not necessarily in lab—computer based, reading articles, creating posters, etc.

O O O O 4. What activities in Biotechnology do you like the least.

a. Lectures, including Disease Wednesday, Breakfast with biotech

b. Lab activities that follow a planned protocol

c. Lab activities that are open-ended (recall or food testing lab in Biotech II)

d. Working in groups on assignments and projects not necessarily in lab—computer based, reading articles, creating posters, etc.

O O O O 5. Do you read materials that contain articles involving Biotech topics? This may be newspapers, internet websites, magazines, etc.

a. Never

b. Sometimes

c. Often

d. Yes, on a regular basis

O O O O 6. What topics in Biotechnology do you like the best?

a. Information about industry and careers

b. DNA based topics including genes and phenotype

c. Protein based studies including quantification and analysis
d. Studying about skills, assays and techniques

a b c d

O O O O 7. Your commitment to the academy curriculum will end in Biotech III. Will you, however, continue in Biotech IV which is *Experimental Science* requiring a research project?
a. I will definitely continue
b. I am not sure if I will continue
c. I will definitely NOT continue

O O O O 8. Do you have a research topic?
a. Yes, I have a defined project
b. I have a topic in mind
c. I have no idea what I can research

O O O O 9. How did you determine the topic of your project? If you do not have a project topic, in your opinion, what is the best way to define a topic to research?
a. Topic based on subjects and skills related to biotech
b. Topic based on current events with which I am familiar
c. Topic is one that will permit considerable parental support
d. Another way to select a topic not described here

O O O O 10. What activity in Biotech do you think will best help one determine a research topic?
a. PCR projects and bioinformatics learned in Biotech I
b. Assay development and protein biochemistry in Biotech III
c. Learning about model organisms in Biotech III
d. Literature and research on a gene to be completed in Biotech III

Survey: Student Attitudes towards Biotechnology III

Please **DO NOT** place your name on this survey. There will be no attempt to place your responses with a name. Pleased answer as honestly as possible.

a b c d

O O O O 1. At the beginning of the school year you were asked why you were taking Biotechnology III. What did you answer-- because you want to, or because you have to?

a. I want to take biotech

b. I have to take biotech because_________________________________

____

O O O O 2. How would you answer the question (1) above today?

a. I would give the same answer

b. My answer would be different

O O O O 3. Your commitment to the academy curriculum will end in Biotech III. When asked in August, "will you, however, continue in Biotech IV which is *Experimental Science* requiring a research project," how did you answer?

a. I will definitely continue

b. I am not sure if I will continue

c. I will definitely NOT continue

O O O O 4. How would you answer the question (3) above today?

a. I would give the same answer

b. My answer would be different

O O O O 5. Do you have a research topic?

a. Yes, I have a defined project

b. I have a topic in mind

c. I have no idea what I can research

O O O O 6. How did you determine the topic of your project. If you do not have a project topic, in your opinion, what is the best way to define a topic to research?

a. Topic based on subjects and skills related to biotech

b. Topic based on current events with which I am familiar

c. Topic is one in which I can have considerable parental support

d. Another way to select a topic not described here

O O O O 7. What activity in Biotech best helped you determine a research topic?

a. PCR projects and bioinformatics learned in Biotech I

b. Assay development and protein biochemistry in Biotech III

c. Learning about model organisms in Biotech III

d. Literature and research on a gene to be completed in Biotech III

Literature Cited:

Brooks,E. ,Dolan, E. and Tax F, (2011) Partnership for Research & Education in Plants (PREP): Involving High School Students in Authentic Research in Collaboration with Scientists, *The American Biology Teacher*, 73(3):137-142.

Hsu,P., Roth, RM. and Mazumder, A. (2009) Natural Pedagogical Conversations in High School Students' Internship, *Journal of Research in Science Teaching*, 46, (5) 481–505

Hunter, a., Laursen,s.a. and Seymour, E. (2007) Becoming a Scientist: The Role of Undergraduate Research in Students' Cognitive, Personal, and Professional Development, *Sci Ed* 91:36 – 74,

Kirk, K.E. and Weiland J. (2006) Trekking Through The Human Genome: An Individualized Laboratory Project, *The American Biology Teacher*, 68(8):e124-e130.

O'Neill, O.K, and Polman, J.L. (2004) Why Educate ''Little Scientists?'' Examining the Potential of Practice-Based Scientific Literacy, *Journal of Research in Science Teaching* 41 (3) 234–266

Vogel, G. (1996) Global review faults U.S. curricula. *Science*,274 (335)

Waight,N. and Abd-El-Khalick, F. (2011) From Scientific Practice to High School Science Classrooms: Transfer of Scientific Technologies and Realizations of Authentic Inquiry *Journal Of Research In Science Teaching* ,48, (1) 37–70

Wefer, S.H (2003) Name That Gene, *The American Biology Teacher*, 65(8):610-613.

Wefer,S.H. and Anderson, O.R. (2008) Identification of Students' Content Mastery and Cognitive and Affective Percepts of a Bioinformatics Mini-unit: A Case Study With Recommendation of Teacher Education*, J Sci Teacher Education*, 19:355-373

Budget and Budget Justification:

JumpStart REDTaq DNA Polymerase	Sigma Chemical	$150
Student created PCR Primers (other funding for additional cost)	Sigma Chemical	Price varies, but will be generally $4-6/ primer

Permissions: Parental Consent to obtain a buccal DNA sample.