Abstract

As careers in biotechnology rise, qualified individuals are needed to fill those positions. Because many of these careers are new, many Americans are not aware of the opportunities they provide to young people as they begin to decide what they want to be when they grow up. This project was designed to increase high school student's exposure to the growing field of biotechnology. Students were given the opportunity to learn some of the skills used in biotechnology by performing electrophoresis, PCR and transformation laboratory exercises as they learn the content related to these practices. In addition, students will be exposed to real time research and the scientists and technicians doing that research throughout the course. At the end of the course, students will progress through a video game _______ exploring careers in biotechnology. As a result students will be able to identify and hopefully begin to pursue paths that will lead them to careers in molecular biology, medicine and biotechnology.

Rationale

“People with Pompe disease cannot produce the enzyme acid alpha-glucosidase, or GAA. Without the enzyme, sugars and starches that are stored in the body as glycogen accumulate
and destroy muscle cells, particularly those of the heart and respiratory muscles. Many patients need ventilators to breathe." (Pastor, 2010)

This statement may not seem significant on its own, of course unless you or a loved one suffers for the disease. However, this disease recently entered the public forum by way of the movie Extraordinary Measures. The film opened in January 2010 highlighting the disease and the work of scientists, like Dr. Byrnes of the University of Florida, as they try to find answers to the multitude of diseases that can afflict any human being at any given point in time. (Dooley, 2010)

Scientists, like Dr. Byrnes, are created in science classrooms across the United States. The teachers in our science classrooms provide the spark and support that lead people like Dr. Byrnes down a path that leads to the discovery of new treatments to diseases to help improve the quality of life for all humans. (Byrnes, 2010)

Unfortunately, we do not find ourselves currently in a position to fill industry’s continuing and increasing need for scientists (and doctors) like Dr. Byrnes. We are unable to keep up with the industry demand for bright and talented individuals with math and science backgrounds. (Payne, 2004)

“Those planning to pursue science and engineering careers will need higher levels of science literacy than most, but perhaps not so obvious is the fact that even nonscientists will need a baseline level of science understanding if they are to become responsible citizens, capable of functioning fully in a technology-driven age.” (Payne, 2004) Science literacy does not come from simply cruising the internet or clicking an ap. As with literacy in all academic disciplines, classroom teachers find themselves in drivers seat. If teachers are expected to provide students with adequate education in science and technology they also need to be educated as science and technology have grown exponentially in the past few decades. The Center for Precollegiate Education and Training (CPET) at the University of Florida has been actively engaged in providing such education/training for teachers for the past 15 years. (Bokor, 2010)
CPETs Bench to Bedside (B2B) program was designed to educate teachers in all aspects of translational research. During a two week period, teachers were immersed in translational research content ranging from bench level pipetting (as scientific skills needed in the discovery phase) through to market production of those same scientific discoveries. The intent of this program is to empower teachers with the skills, knowledge and possible applications needed to bring this information into the classroom. In doing so, students may be stimulated to pursue avenues in biotechnology (whether as a craft or as research scientists and MDs) or, at the very least, become more scientifically literate. With either outcome, CPET participants are B2B able to begin addressing some of the concerns regarding industry needs in emerging careers in science and biotechnology as well as scientific literacy in the population in general.

The target group for this project is a class of AP biology students. The majority of the students are in their sophomore year in high school (age 15+/-). While the AP Biology curriculum runs wide and deep, there is a need for these students to engage in aspects of biotechnology as both trends and skills in the biological sciences are increasingly requiring students be competent in the concepts and techniques commonly used in current (and future) scientific research. All of the content and techniques learned during the B2B program speak directly to this component of the AP Biology curriculum. At the beginning of the course, students will be surveyed regarding any previous knowledge of career options an AP biology course might open doors to. As the course progresses, relevant names and places of real scientists doing real work will be used to provide content relevance to real life application. For example, as the course moves through simple chemistry to the properties of water and into macromolecules, the process of protein crystallization can be referenced to demonstrate application of all of that content knowledge. The result of crystallization and protein structure reinforces all concepts related to protein function. Because protein function is related to metabolism control, genetic and evolutionary
concepts are previewed to be reinforced later as that content is discussed. Discussion of genetic disorders currently being researched regarding carbohydrate metabolism make understanding the role of those macromolecules relevant (both type I diabetes as well as GSD). Students will be required to research and report on two scientists and their body of work. One scientist must be dead and the other must be alive and currently actively working in their field. In both cases, students will have to focus on the work of the scientist and its impact on humanity.

Students will engage in DNA extraction, chromatography (plant pigment for chromatography concepts), electrophoresis, DNA ligation and transformation laboratory exercises. If time permits, students will perform simulated microarray testing. After the AP biology exam, students will make trip to UF to tour/visit/meet some of the research facilities and people referenced throughout the course.

The CPET B2B has opened the door for these students to access real time science in action. As a participant, I was made aware of a multitude of research opportunities available to students. In addition to research opportunities, skill related careers were also highlighted during the course of the program. Besides awareness, the B2B program has given me access to some biotech equipment/materials that my student would not otherwise have the opportunity to be exposed to. Students would not be exposed to e-gel, PCR and microarray simulation beyond the textbook and online simulations without access to these materials via B2B. In addition, course/student information will be shared with Dr. Troy Sadler for his Mission Biotech project.

NOTE: If this is done with a Genetics class rather than an AP bio class, genetics students will actively participate in the Mission Biotech program.
The initial biotechnology careers survey will be used pre and post course to determine if student awareness of biotech careers changes as a result of information from B2B inserted into the curriculum. Pre and post testing during the DNA technology section of the course will be used to determine if student gains are made.

Students will watch Extraordinary Measures and identify when/where content knowledge and biotech careers were applied in the movie.

If this is used with a genetics class, the required data analysis documents will be used for data collection and analysis.

**Works Cited**


Class (~24 student/ max 3 per group = total 8 stations) set of e-gel electrophoresis materials.

Class set of DNA ligation materials.
Class set of simulated microarray assay.

Check county policy for required permissions for sharing student data/pictures/work.
Bench to Bedside

Transitioning students
The Problem

Students need to develop real laboratory skills

High school classrooms often engage students in “hands on” activities that do not necessarily develop usable science laboratory skills.

Teaching students usable laboratory skills and the necessary purpose of those skills gives them the Tools needed to engage in real laboratory analysis.
The Problem

Students need to “see” scientists as real people.

And science as a career option.

High school often learn about scientists as ‘a bunch of DEAD GUYS’.

The work of scientists is often seen as something.

The nameless/faceless “THEY” engage in.
Students develop science skills

Scientists are living, breathing people with relevant contributions

Students with skills imagine themselves as scientists
The Solution

Teachers participate in Bench to Bedside
- Teachers learn relevant laboratory skills
- Teachers meet living scientists making relevant contributions

Teachers incorporate Bench to Bedside in the classroom
- Students learn relevant laboratory skills
- Students learn about living contributing scientists and their work

Students imagine themselves as scientists
- Students develop laboratory skills and apply them in real scientific endeavors
- Students ‘meet’ living scientists and with their new found skills, imagine themselves in science careers
Develop science skills

• Bench to Bedside participants engage in developing science skills

• The same materials/equipment are made available for use by students in science classrooms

• Skills developed:
  – micropipetting
  – Electrophoresis
  – Transformation
  – Protein crystallization
  – Microarray
  – To follow Mission Biotech
Scientists are people

• Bench to Bedside participants meet many real scientists and are exposed to their current research projects

• Information is relayed to students on a regular basis as student are moved through content

• Students report on scientists both DEAD and ALIVE. Contact with living scientists required.

• Students read and share *Demon in the Freezer*, *Your Inner Fish* and *Survival of the Sickest*
Evidence of student transition

• Without control groups, it is not possible to determine outcomes for students not engaged in these activities. It would be unethical to deny some students the benefit of exposure to this information for the sake of generating data. As a result, data must be considered on its own merit.

• Student knowledge of scientists and their contributions were utilized in pre and post evaluations to determine changes in student perceptions/knowledge of scientists and scientific work. This may not be an accurate measurement of student attitudes towards science as a career, but it does demonstrate significant growth in awareness as a first and very crucial step.

• Career potential data to follow
Table 1: predata: Student knowledge of scientists and scientific contributions

<table>
<thead>
<tr>
<th></th>
<th>Number of students</th>
<th>Total scientists</th>
<th>Dead</th>
<th>alive</th>
<th>Total accomplishments</th>
<th>Dead accomplishments</th>
<th>Alive accomplishments</th>
</tr>
</thead>
<tbody>
<tr>
<td>total</td>
<td>21</td>
<td>63</td>
<td>51</td>
<td>12</td>
<td>20</td>
<td>16</td>
<td>3</td>
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<td>0-5</td>
<td>0-1</td>
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<tr>
<td>mean</td>
<td>3</td>
<td>2.43</td>
<td>0.57</td>
<td>0.95</td>
<td>0.76</td>
<td>0.14</td>
<td></td>
</tr>
</tbody>
</table>
### Dead scientists include:

- Thomas Jefferson
- Theodore Roosevelt
- Albert Einstein
- Isaac Newton
- Thomas Edison
- Johannes Kepler
- Aristotle
- Plato
- Darwin
- Lamark
- Leonardo DaVinci
- Tesla
- Mandel
- Hopaihemer
- Madame Curie
- Pierre Curie
- Mendez
- Larment
- Franklin
- Jenner
- Boyle
- Mendel
- Pastuer

- 69% of dead scientist accomplishments were accurate, although vague (i.e. Newton developed Laws of Physics)

### Living scientists include:

- Teacher
- Bill Nye
- Dr. Eberbock
Table 2: postdata: Student knowledge of scientists and scientific contributions

<table>
<thead>
<tr>
<th></th>
<th>Number of students</th>
<th>Total scientists</th>
<th>Dead</th>
<th>alive</th>
<th>Total accomplishments</th>
<th>Dead accomplishments</th>
<th>Alive accomplishments</th>
</tr>
</thead>
<tbody>
<tr>
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<td>142</td>
<td>48</td>
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<td>142</td>
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<td>1-19</td>
<td>0-13</td>
<td>1-8</td>
<td></td>
</tr>
<tr>
<td>mean</td>
<td>10.55</td>
<td>7.88</td>
<td>2.66</td>
<td>10.55</td>
<td>7.88</td>
<td>2.66</td>
<td></td>
</tr>
</tbody>
</table>
## Postdata

### Dead Scientists include:

- Sir Isaac Newton  
- Rosalind Franklin  
- Darwin  
- Albert Einstein  
- Newton  
- Koch  
- Galileo  
- Messeloson and Stahl  
- Franklin Rosavelt  
- VonStriser  
- Hardy Weinburg  
- Thomas  
- Garrod  

<table>
<thead>
<tr>
<th></th>
<th>Leeuwenhoek</th>
<th>Mendel</th>
<th>Watson and Crick</th>
<th>Macleod</th>
<th>Erwin Chargoff</th>
<th>Stanley Miller</th>
<th>Wallace</th>
<th>Bohr</th>
<th>Rachel Carson</th>
<th>Thomas Morgan</th>
<th>Wilmut</th>
<th>Galilgeo</th>
<th>Aristotle</th>
<th>Lamark</th>
<th>Frederick Griffith</th>
<th>Tatum and Beadle</th>
<th>Hombhemeer</th>
<th>Pastuer</th>
<th>Kanger</th>
<th>Keuwenhoeld</th>
<th>Hershey</th>
<th>Charoff</th>
<th>Wilmont</th>
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<tr>
<td>Sir Isaac Newton</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td>Erwin Chargoff</td>
<td></td>
<td></td>
<td>Stanley Miller</td>
<td></td>
<td>Wilmut</td>
<td>Galilgeo</td>
<td>Aristotle</td>
<td>Lamark</td>
</tr>
</tbody>
</table>
Alive Scientists include:

- Craig Venter
- Hamilton Smith
- Neil Shubin
- D.A. Henderson
- Peter Jahrling
- Gunna
- Muller
- Wilmut
- Okazaki
- Sharon Moalem
- Jane Goodall
- Richard Dawson
- Richard Dawkins

90% of scientists were accurately identified with their accomplishment

** some names were unidentifiable and counted as incorrect

*** fictional characters identified as scientists included. The significance of this is the topic of a separate study
Data Analysis

• Total scientists
  – 63/21 increase to 190/18
  – average 3 increase to 10.55 (~3X)

• DEAD
  – 51/21 increased to 142/18
  – average 2.43 increased to 7.88 (~3X)

• ALIVE
  – 12/21 increased to 48/18
  – Average 0.57 increased to 2.88 (~5X)
Data Analysis

• Scientist accomplishments
  • Total
    – 20/21 improved to 190/18
    – Average 0.95 improved to 10.55 (~10X)
  • DEAD
    – 16/21 improved to 142/18
    – Average 0.76 improved to 7.88 (~10X)
  • ALIVE
    – 3/21 improved to 48/18
    – Average 0.14 improved to 2.66 (~19X)
Conclusion

• Allowing students to develop laboratory skills relevant to real science and exposing them to living scientists utilizing those same skills serves to illuminate SCIENCE as a viable career choice for high school students. Science and scientific work becomes real and relevant.

• Well educated and trained teachers make this possible.
BIOTECHNOLOGY CAREERS

Biotechnology Careers
Preparing High School Students

Laura Bushwitz, NBCT, MAT, MT
East Ridge High School
University of Florida Center for Precollegiate Education and Training
June 20 – July 2, 2010
Abstract

As careers in biotechnology rise, qualified individuals are needed to fill those positions. Because many of these careers are new, many Americans are not aware of the opportunities they provide to young people as they begin to decide what they want to be when they grow up. This project was designed to increase high school student’s exposure to the growing field of biotechnology. High school AP Biology students (primarily sophomores) were given the opportunity to learn some of the skills used in biotechnology by performing electrophoresis, transformation, protein crystallization and simulated biotechnology laboratory exercises as they learn the content related to these practices. In addition, students were exposed to real time research and the scientists and technicians doing that research throughout the course. As a result, students were able to identify and hopefully begin to pursue paths that will lead them to careers in molecular biology, medicine and biotechnology. In the process they gained technical skills used in those same careers. Students were given a pre and post assessment to determine their knowledge of scientists and scientific work. Student knowledge of scientists and science careers increased significantly after participating in laboratory activities that specifically addressed biotechnology skills, real time research projects/presentations on scientists (both dead and alive), reading assignments (Your Inner Fish, Survival of the Sickest, Demon in the Freezer), and exposure to scientists and their contributions as students moved through biology content. In addition to in class exposure to biotechnology, an extracurricular organization, Science National Honor Society (SNHS) was developed at student request. These students were also given the opportunity to gain biotechnology skills and advance their knowledge of the research process utilizing laboratory materials and scientific access made available via the Bench to Bedside program. As a result, four SNHS members attended the Junior Science, Engineering and Humanities Symposium for the first time with the goal of gaining information that will allow them to develop their own research projects for the SNHS to potentially present at future Symposia. Both teacher and student exposure to these opportunities have opened the possibility of implementing a Biotechnology Program on campus. Biotechnology I classes are currently open for enrollment for the 2011-12 school year. Development of a Biotechnology Certification program for students is also currently being investigated.
Rationale

“People with Pompe disease cannot produce the enzyme acid alpha-glucosidase, or GAA. Without the enzyme, sugars and starches that are stored in the body as glycogen accumulate and destroy muscle cells, particularly those of the heart and respiratory muscles. Many patients need ventilators to breathe.” (Pastor, 2010)

This statement may not seem significant on its own, of course unless you or a loved one suffers for the disease. However, this disease recently entered the public forum by way of the movie *Extraordinary Measures*. The film opened in January 2010 highlighting the disease and the work of scientists, like Dr. Byrnes of the University of Florida, as they try to find answers to the multitude of diseases that can afflict any human being at any given point in time. (Dooley, 2010)

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Unfortunately, we do not find ourselves currently in a position to fill industry’s continuing and increasing need for scientists (and doctors) like Dr. Byrnes. We are unable to keep up with the industry demand for bright and talented individuals with math and science backgrounds. (Payne, 2004)

“Those planning to pursue science and engineering careers will need higher levels of science literacy than most, but perhaps not so obvious is the fact that even nonscientists will need a baseline level of science understanding if they are to become responsible citizens, capable of functioning fully in a technology-driven age.” (Payne, 2004) Science literacy does not come
from simply cruising the internet or clicking an ap. As with literacy in all academic disciplines, classroom teachers find themselves in drivers seat.

If teachers are expected to provide students with an adequate education in science and technology they too need to be educated as science and technology have grown exponentially in the past few decades. The Center for Precollegiate Education and Training (CPET) at the University of Florida has been actively engaged in providing such education/training for teachers for the past 15 years. (Bokor, 2010) CPETs Bench to Bedside (B2B) program was designed to educate teachers in all aspects of translational research. During a two week period, teachers are immersed in translational research content ranging from bench level pipetting (as scientific skills needed in the discovery phase) through market production of those same scientific discoveries. The intent of this program is to empower teachers with the skills, knowledge and possible applications needed to bring this information into the classroom. In doing so, students may be stimulated to pursue careers in biotechnology (whether as a craft or as research scientists and MDs) or, at the very least, become more scientifically literate. With either outcome, CPET participants in B2B are able to begin addressing some of the concerns regarding industry needs for emerging careers in science and biotechnology and are able to improve scientific literacy in the population in general.
Action Research Intervention

The target group for this project is a class of AP biology students. The majority of the students are in their sophomore year in high school (age 15+/-). The AP Biology curriculum runs wide and deep and includes requirements for student engagement in aspects of biotechnology as related to modern DNA technology techniques. Trends in the biological sciences are increasingly requiring student competence in concepts and techniques commonly used in current (and future) scientific research. All of the content and techniques learned during the B2B program speak directly to this component of the AP Biology curriculum.

At the beginning of the course, students were surveyed to determine previous knowledge regarding scientists and their scientific contributions. This type of content knowledge is often presented as names/dates/places to be memorized for some type of test at some point in time. The relevance of these scientists and their work rarely progresses beyond this anticipated test. In this course, however, names and places of real scientists doing real work were used to provide content relevance via real life application.

For example, as the course moved through simple chemistry (atomic structure), discussion regarding Bohr and the development of the Bohr model began the journey to understanding all that we know in science came about by the work of scientists, real people trying to explain how the natural world works. As the class progressed from the properties of water to macromolecules, the process of protein crystallization was referenced (and later performed) to demonstrate how content knowledge and biotechnology skills could be applied to benefit humanity. To accomplish protein crystallization, students had to develop micropipetting skills, a common practice in the research laboratory. In addition to pipetting skills, students had use trial and error to find the right dilutions of dehydrating solutions for protein crystallization.
As students began to master these skills, they also began to recognize they were capable of doing real science. The result of protein crystallization and protein structure reinforced all concepts related to protein function. Because protein function is related to control of metabolism, genetic and evolutionary concepts are previewed to be reinforced later as that content is discussed. The use of x-ray crystallography to determine protein shape (and amino acid sequence) as well as DNA shape was made a reality. The existence of an x-ray crystallography machine in the McKenna Lab at the University of Florida and its use to identify protein shape for viral vectors, served to make this type of scientific research real rather than something you read about.

Discussion of genetic disorders currently being researched regarding carbohydrate metabolism made understanding the role of those macromolecules relevant (both type I diabetes as well as GSD). In this particular class, this information became significantly more relevant as one student in this class had Type I diabetes. Continuous addition of relevant real time scientific work into content discussion became the norm as the class progressed.

Students also developed laboratory skills by extracting DNA, performing chromatography (plant pigment for chromatography concepts), DNA electrophoresis (as crime scene investigation and restriction enzyme digest), and transformation (inserting a plasmid into \textit{E. Coli} conferring antibiotic resistance) laboratory exercises. Students also performed simulated microarray testing as they looked for water contaminants, local flora diseases and infectious diseases. As students continued to develop biotechnology skills while performing relevant biotechnology testing, they began to develop the notion that they might be able to pursue careers in biotechnology and research to answer some of the questions we still have regarding human diseases.
Students were also required to research and report on two scientists and their body of work. One scientist had to be dead and the other had to be alive and currently actively working in their field. In both cases, students had to focus on the work of the scientist and its impact on humanity. Students were also required to read one of three books *Demon in the Freezer, Survival of the Sickest*, or *Your Inner Fish*. All three of these books are written by modern day scientists. Students were required to work in groups to present the content of their specific book to the class. As with the reading presentations, students had to share their scientist research with the class. The intent of focusing on these activities was to bring science and scientists alive. Too often scientists are seen as nothing more than those named faceless dead guys you have to memorize for ‘that test’. Instead, bringing science alive via and living, breathing people with very do-able skills presents science as a viable career option for high school students. The three books and scientist reports were referenced routinely as the class moved through content reinforcing the relevance of their scientific contributions. In this respect students are continuously reminded that science is an ongoing real life endeavor done by people just like them.

**Connections to Bench to Bedside summer institute**

The CPET B2B opened the door for these students to access real time science in action. As a participant, I was made aware of a multitude of research opportunities available to students. In addition to research opportunities, skill related careers were also highlighted during the course of the program. Besides awareness, the B2B program gave me and my student’s access to biotech equipment/materials that we would not otherwise have the opportunity to be exposed to. Without B2B, students would not be exposed to extensive micropipetting protein crystallization materials, e-gel and microarray simulation beyond the textbook or online simulations. Students
would not have the opportunity to develop these skills so common to the research laboratory experience. This exposure opens doors as students begin to see they are capable of doing real science. They begin to see scientists as living breathing people that do critically important work that makes life better for everyone. As they progress through the course they begin to recognize they are capable of pursuing a career in science to answer some of the questions we still have.

As an added note, by student request, an extracurricular club, the Science National Honor Society (SNHS) was organized. This group of highly motivated students also took the opportunity to utilize laboratory activities made available via B2B. As a result, four students voluntarily attended this year’s Junior Science, Engineering and Humanities Symposium (JSEHS). These students attended to gather information that will allow them to better develop their own research projects (with the SNHS) for next year’s JSEHS.

**Data Collection and Analysis**

There are several methods that might be employed to determine whether or not student awareness of biotechnology careers or biotechnology skills improved pre and post lesson. Given that students come in with no skills or previous knowledge of biotechnology, improvements would be obvious. Students would not have had the opportunity to engage in any of the biotechnology laboratory activities if they were not in this specific class. These are facts that do not require data for support.

The job of science educators should be more than simply introducing students to new career possibilities. Students should also be motivated to pursue those careers as our next generation of scientists. Doing so requires a transition in the way students think about science and scientists. Science needs to be taught as a noble endeavor performed by those that develop specific skills
needed to help answer the questions we have about how the world works. Modern science, specifically the biological sciences, provides abundant opportunities for young people to do just that. Students need to see themselves as scientists if they are to consider becoming the next generation of scientists. With this in mind, the data collected for this project involved gleaning student knowledge of scientists and their contributions as pre (beginning of school, August) and post (midterm, January) lesson data sets. A control group, students taking the same course but in a different teachers class, we asked for the same information (midterm, February).

Table 1 documents the test group pre lesson data. Students were asked to name any scientists they knew, both dead and alive, and to identify the contributions of those scientists. 21 students participated by naming 63 scientists (51 dead, 12 alive). Only 20 accomplishments were identified and of those 20 accomplishments only 11/16 (69%) were accurately identified, although those accomplishments were vague (i.e. Newton developed Laws of Physics, Edison invented light bulb). It is notable that some scientists listed were not scientists. This is an important bit of information as there exists a plethora of inaccurate (or, at best, misleading) “scientific” information available via the internet and in media in general. Two examples include The Pacific Northwest Tree Octopus (Zapato, 1998) and DHMO (Way) websites. While this was not an original consideration in conducting this research, it does lend itself to the need to improve scientific literacy in the general population.

Table 2 documents the same information in the test group post lesson. 18 students participated, identifying 190 scientists (142 dead, 48 alive). This is a three fold increase. All scientists identified were associated with a scientific accomplishment. 171/190 of those accomplishments (90%) were accurately identified with the scientist. It is notable that the live scientists identified were all actual scientists. This is a significant improvement over the course of 5 months.
Table 3 documents the same information from the CONTROL group. The Control group is an AP Biology class with the same general demographics as the test group. It is mandatory for AP Biology classes to engage in some of the same laboratory exercises (specifically electrophoresis, pigment chromatography and transformation). In this respect, the students in the Control group did encounter some of the same biotechnology experiences; however, because they had a different teacher they did not have access to the same equipment, materials, scientist exposure as the test group. The data from the control group was collected approximately one month after the test groups post lesson data was collected. The Control group contained 22 students that identified 133 scientists (128 dead and 5 alive). Students identified 111 accomplishments (contributions) by the scientists they identified, however, only 40/111 (36%) of these accomplishments were accurately identified, although those accomplishments were vague (i.e. Mendel studied peas, Darwin: evolution, Benjamin Franklin discovered electricity, etc.). As mentioned previously, it is notable that some of the scientists named were not actually scientists. The control group data could be compared to the test group pre data; however, the students had covered the bulk of biotechnology related content at the time of data collection. If compared to test group pre lesson data, the control group identified 2x as many scientists, however, their identified scientific contributions were far less accurate than the test group pre lesson data despite having covered AP content for 5 months (while test group pre data was obtained with no content covered). If compared to test group post lesson data, there is not only a significant difference in the accuracy of scientist/accomplishment, there is also a significant difference in the number of scientists (dead and alive) identified.

The only true information that can be gleaned from this data is that the test group has a greater awareness of scientists, both dead and alive, and their scientific contributions. This awareness improved over the course of the lessons they were engaged in. Because the Control group and Test group were exposed to similar content, it must be assumed that the test group was
able to demonstrate this improvement because of the manner in which they were exposed to content. The B2B program provided me with experience and exposure to information and materials that directly impacted those students under my guidance. The Test group experience, based on knowledge of scientists, is significantly different from the experience of the Control group students. While it is difficult to determine if this difference in experience will lead to a higher percentage of ‘future research scientists’ in the test group, it may be assumed that the test group has had greater exposure to biotechnology techniques and the application of those techniques to content and real science because they had access to a B2B teacher.
Works Cited

Bokor, J. (2010, July 1). Assistant Director CPET. Bench to Bedside Summer program interview. Gainesville, FL, USA: Laura Bushwitz interviewer.


Budget and budget justification

Class set of micropipette practice activity (protocol, pipettes, ELISA trays)

Class (~24 student/ max 3 per group = total 8 stations)
  set of e-gel electrophoresis materials. (AP lab 6)
  set of transformation materials

Class set of simulated microarray assay.

Class set (plus 10) of protein crystallization materials.
  Class and Science national Honor Society Members will participate in this lab.

JSEHS attendance X4 students, X2 chaperones.
Reflection

Exposing students to skills, knowledge and opportunities in the science arena is an undying passion of mine. It is the reason I moved into education after 20+ years as a Medical Technologist. Having access to active labs, the scientists running those labs and lab activities/equipment/materials made it much easier to bring these opportunities into my classroom. Far too often science teachers are forced to engage students in ‘make pretend’ science activities. Exposure to real science is absolutely necessary if we are expected to develop the next generation of scientists. My students were able to develop real skills used in real research laboratories. As we plowed through content, they were able to recognize the relevance of that content and the skills they were developing.

I would like to have been able to bring students to a research laboratory and have them interact with the scientists. While a few students in the SNHS were able to do this and students were given the opportunity to interact with a live scientist via their reports, more exposure (perhaps a field trip to a lab) could have made a greater impact on science careers as viable career options.

I would also like to coordinate the use of laboratory equipment to better match ongoing coverage of content in the classroom. Because of time constraints and availability of materials from the borrowed equipment locker, some biotech lab activities were performed a bit ‘out of context’, meaning we did them while we had the materials rather than while we were focused on the relevant curriculum. While this did not present a problem regarding student understanding, I would have preferred smoother movement from content into lab experiences.

The original plan included engaging students in Mission Biotech. Because of time constraints, this portion of the plan had to be deleted. In addition, since this group of students had engaged in actual laboratory experiments or simulations, a virtual program did not seem an
efficient use of time. The program may have been used if it was more readily available for use earlier in the year rather than after actual laboratory experiment had been conducted.

One of the major reasons teachers continue to engage students in make pretend science is their lack of experience and confidence in conducting actual science experiments. According to McGinnis and Harris, students assimilate content better when engaging in genuine activities. The best way for teachers to engage their students in genuine activities at the secondary level is to build confidence in their ability to do so. This could certainly be done having teachers with the type of experience acquired in the Bench to Bedside program share those experiences and the lesson plans developed for students as a result of those experiences. While development of lessons utilizing biotechnology (from bench to bedside) is an ongoing process, sharing experiences via collaboration and conferences would be an activity that I would readily participate in to help disseminate this information to secondary science teachers and eventually their students.
B2B Action Research data

Test Group pre lesson Data

Purpose: Increase student knowledge of scientific careers

Before: ID scientists both dead and alive and ID what their scientific contribution was.

TABLE 1

Initial Survey of Student Knowledge of Scientists, DEAD and ALIVE, and Their Scientific Contributions

<table>
<thead>
<tr>
<th></th>
<th>Number of students</th>
<th>Total scientists</th>
<th>Dead accomplishments</th>
<th>Alive accomplishments</th>
</tr>
</thead>
<tbody>
<tr>
<td>total</td>
<td>21</td>
<td>63</td>
<td>51</td>
<td>12</td>
</tr>
<tr>
<td>range</td>
<td>1-7</td>
<td>0-6</td>
<td>0-2</td>
<td>0-5</td>
</tr>
<tr>
<td>mean</td>
<td>3</td>
<td>2.43</td>
<td>0.57</td>
<td>0.95</td>
</tr>
</tbody>
</table>

11 of 16 (69%) of dead scientist accomplishments were accurate, although vague (i.e. Newton developed Laws of Physics, Edison invented light bulb)

Teacher was identified as a living scientist because of industry experience prior to entering education by one student and because of teaching experience by another student.

NOTE: This is an AP Biology class. Pre data was collected prior to covering and AP Biology content. Pre data therefore represents student knowledge prior to taking this specific course.
### Scientist names Test Group pre lesson

#### DEAD

<table>
<thead>
<tr>
<th>Name</th>
<th>Name</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thomas Jefferson</td>
<td>Darwin 1</td>
<td>Mendelz</td>
</tr>
<tr>
<td>Theodore Roosevelt</td>
<td>Lamark 1</td>
<td>Larment</td>
</tr>
<tr>
<td>Albert Einstein</td>
<td>Leonardo DaVinci</td>
<td>Franklin</td>
</tr>
<tr>
<td>Isaac Newton</td>
<td>Tesla</td>
<td>Jenner</td>
</tr>
<tr>
<td>Thomas Edison</td>
<td>Mandel</td>
<td>Boyle</td>
</tr>
<tr>
<td>Johannes Keppler</td>
<td>Hopaihemer</td>
<td>Mendel</td>
</tr>
<tr>
<td>Aristotle</td>
<td>Madame Curie</td>
<td>Pastuer</td>
</tr>
<tr>
<td>Plato</td>
<td>Pierre Curie</td>
<td></td>
</tr>
</tbody>
</table>

#### ALIVE

<table>
<thead>
<tr>
<th>Name</th>
<th>Name</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher 111111111</td>
<td>Bill Nye</td>
<td>Dr. Eberbock</td>
</tr>
</tbody>
</table>
Test Group POST lesson Data

Collected after first $\frac{1}{2}$ year of content exposure, biotechnology content and activities (electrophoresis, transformation, microarray analysis), reading assignments (Survival of the Sickest, Demon in the Freezer, Your Inner Fish) and scientist report assignments and presentations.

TABLE 2

Secondary Survey of Student Knowledge of Scientists, DEAD and ALIVE, and Their Scientific Contributions. Survey conducted halfway through the term (5 months after original survey)

<table>
<thead>
<tr>
<th></th>
<th>Number of students</th>
<th>Total scientists</th>
<th>Dead accomplishments</th>
<th>alive accomplishments</th>
<th>Total accomplishments</th>
<th>Dead accomplishments</th>
<th>Alive accomplishments</th>
</tr>
</thead>
<tbody>
<tr>
<td>total</td>
<td>18</td>
<td>190</td>
<td>142</td>
<td>48</td>
<td>190</td>
<td>142</td>
<td>48</td>
</tr>
<tr>
<td>range</td>
<td></td>
<td></td>
<td>0-13</td>
<td>1-8</td>
<td>1-19</td>
<td>0-13</td>
<td>1-8</td>
</tr>
<tr>
<td>mean</td>
<td></td>
<td></td>
<td>10.55</td>
<td>7.88</td>
<td>10.55</td>
<td>7.88</td>
<td>2.66</td>
</tr>
</tbody>
</table>

171/190 (90%) scientists correctly identified with their accomplishment. Some Scientists unidentifiable (i.e. spelling of name) and not considered correct. Three “scientists” identified were fictional; characters in movies/video games. These were included in the data because of the importance of understanding students association of true scientific work with fictional world. While teachers may wish to ignore such associations as student silliness, the reality is student thoughts regarding science, rightly or wrongly, may be dominated by what is presented in entertainment media. As entertainment media is not driven by any desire/need to educate the American public, it is critical that teachers recognize the need to be aware of, and when necessary, correct entertainment media generated misconceptions.
## Test Group POST DATA Scientist Names

### DEAD

<table>
<thead>
<tr>
<th>Scientist Names</th>
<th>Rachel Carson 1111111111</th>
<th>Pastuer 1111</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sir Isaac Newton</td>
<td>Leeuwenhoek 11111111</td>
<td>Mendel 1111111111</td>
</tr>
<tr>
<td>Leeuwenhoek 11111</td>
<td>Thomas Morgan 1111111</td>
<td>Rosalind Franklin 11111111</td>
</tr>
<tr>
<td>Mendel 11111111111</td>
<td>Koch 11</td>
<td>Watson and Crick 11111111</td>
</tr>
<tr>
<td>Rosalind Franklin 111111111</td>
<td>Wilmut</td>
<td>Macleod</td>
</tr>
<tr>
<td>Watson and Crick 11111111</td>
<td>Galilgeo</td>
<td>Darwin 11111111111</td>
</tr>
<tr>
<td>Macleod</td>
<td>Galileo</td>
<td>Erwin Chargoff 11</td>
</tr>
<tr>
<td>Darwin 11111111111</td>
<td>Aristotle</td>
<td>Stanley Miller 1111</td>
</tr>
<tr>
<td>Erwin Chargoff 1</td>
<td>Lamark 111</td>
<td>Albert Einstein 11</td>
</tr>
<tr>
<td>Stanley Miller 1111</td>
<td>Messelson and Stahl 1111</td>
<td>Tatum and Beadle 1111</td>
</tr>
<tr>
<td>Albert Einstein 11</td>
<td>Frederick Griffith 11</td>
<td>Garrod</td>
</tr>
<tr>
<td>Wallace 1111</td>
<td>Franklin Rosavelt</td>
<td>Fictional characters in movies 111</td>
</tr>
<tr>
<td>Bohr 1111</td>
<td>Hombhemer</td>
<td></td>
</tr>
</tbody>
</table>

### ALIVE

<table>
<thead>
<tr>
<th>Scientist Names</th>
<th>Neil Shubin 11111111</th>
<th>Peter Jahrling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Craig Venter 1111111</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hamilton Smith 111</td>
<td>D.A. Henderson</td>
<td>Gunna 1111</td>
</tr>
<tr>
<td>Muller 11</td>
<td>Sharon Moalem</td>
<td>Richard Dawkins</td>
</tr>
<tr>
<td>Wilmut 11111</td>
<td>Jane Goodall 11111</td>
<td></td>
</tr>
<tr>
<td>Okazaki 1</td>
<td>Richard Dawson</td>
<td></td>
</tr>
</tbody>
</table>
Table 3  Control Group DATA

Survey of Student Knowledge of Scientists, DEAD and ALIVE, and Their Scientific Contributions by Students NOT exposed to Bench to Bedside Opportunities/Lessons.

***Survey conducted half way through the term

~5 months after start of course

~ 3 WEEKS AFTER SECONDARY SURVEY TEST GROUP POST LESSON DATA WAS COLLECTED

<table>
<thead>
<tr>
<th></th>
<th>Number of students</th>
<th>Total scientists</th>
<th>Dead accomplishments</th>
<th>alive accomplishments</th>
<th>Total accomplishments</th>
<th>Dead accomplishments</th>
<th>Alive accomplishments</th>
</tr>
</thead>
<tbody>
<tr>
<td>total</td>
<td>22</td>
<td>133</td>
<td>128</td>
<td>5</td>
<td>111</td>
<td>110</td>
<td>1</td>
</tr>
<tr>
<td>range</td>
<td></td>
<td>0-10</td>
<td>0-10</td>
<td>0-2</td>
<td>0-7</td>
<td>0-7</td>
<td>0-1</td>
</tr>
<tr>
<td>mean</td>
<td></td>
<td>6.0</td>
<td>5.8</td>
<td>0.23</td>
<td>5.04</td>
<td>5</td>
<td>0.045</td>
</tr>
</tbody>
</table>

40/111 (36%) of scientist accomplishments were accurately identified (with scientist), although those accomplishments were vague (i.e. Mendel studied peas, Darwin: evolution, Benjamin Franklin discovered electricity, etc.).

NOTE: This control class is also an AP Biology class. This class is covering the same content at the same time. Both the test group and the control group had covered the same content when data was collected at the mid year point (POST test group activities/content). No pre course data was collected on this group.
Control Group Scientist names

**DEAD**

Darwin 1111111111111111  
Carver 1  
Mendel 111111111  
Watson and Crick 11111  
Cuvier  
Lamark  
Galileo 11111111111  
Newton 111111111111111  
Edison 11  
Einstein 1111111111111  
Copernicus 1

Ptolemy 11  
Hardy and Weinburg 1111  
McKlintock  
Thomas Jefferson  
B.F.Skinner 1  
DeCartes  
Aristotle 1111  
Pastuer 11  
Freud 111  
Benjamin Franklin 111

Morris  
Hooke  
Lennon  
Da Vinci 1  
Linneaus 1  
Hippocrates  
Marie Curie 11  
William Wundt  
Wegner  
Earlenmeyer  
Lyell

**ALIVE**

Bill Nye 1  
Al Gore  
Jane Godall 1