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High School Students as Crime Solvers: Experiencing a Practical Application of Genetic Technology

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ABSTRACT *Students experience polymerase chain reaction and DNA fingerprinting techniques to solve a hypothetical crime in a biotechnology unit in regular biology course. In the process, they learn about the connections between the scientific knowledge of the structure of DNA, genetic technologies emerging from that knowledge, and applications of these technologies in modern society.*

KEY WORDS: *Genetic technology instruction, Science-Technology-Society, biology.*

Introduction

The US National Science Education Standards (NSES; National Research Council, 1996) placed the association between science and technology, and between science and community within the science content standards. These are identified, respectively, as the Science and Technology Standards and Science in Personal and Social Perspectives Standards. Placing them within the science content standards indicates their significance as being equal to what has traditionally been considered the content of science. Earlier, the National Science Teachers Association (NSTA) recognized the significance of addressing the connections between science, technology, and society, and adopted an official position on an instructional approach known as Science-Technology-Society (STS). STS can be defined as the teaching and learning of science and technology in the context of human experience. The NSTA position on STS states that:

> *"The bottom line in STS is the involvement of learners in experiences and issues which are directly related to their lives. STS develops students with skills, which allow them to become active, responsible citizens by responding to issues which impact their lives" (NSTA, 1990-91, p. 48).*

In recent years, we had a new realization of the importance of making these connections between science, technology, and society in order to make science interesting, meaningful, and relevant to our students. This realization was the result of seeing students disinterested in our science classes, in spite of our best efforts at making the classes interesting by using laboratory experiments, group activities, and special projects. We decided to use some elements of the STS approach in order to attract our students to science. One of the areas of our high school biology curriculum that lends itself more easily and directly to current societal concerns is the use of genetic technology. Within our curriculum, it connects

with the topics of cells, biotechnology, and genetics. Hence, we chose to use the theme of genetic technology in order to approach the topics of cell, biotechnology, and genetics in a way that establishes real-life relevance of these topics and makes it more interesting to our students. There are many on-line resources of information and activities that relate to the use of genetic technology in school science instruction (see a list of selected web-sites in the Appendix), as well as print resources in practitioner journals, such as *The American Biology Teacher,* and *The Science Teacher.* However, we chose to use the following activity due to its "wet lab" component that provided students with first-hand experience in actually running DNA electrophoresis to find a match between DNA sample collected at a crime scene and several suspect DNA samples. This gave them a much more authentic experience in the use of this genetic technology than can be obtained through on-line simulations or modeling activities (paper DNA, candy DNA, etc).

Genetic Technology in Society

In the unit on cells and biotechnology in our regular biology course, we employed the STS approach to accomplish the following objectives.

- Acquire abilities necessary to carry out scientific investigations.
- Develop an understanding of the structure and functions of cell.
- Understand the molecular basis of heredity.
- Develop an understanding of some common genetic technologies and their practical applications in modern society.

But the main focus of the "crime scene investigation" activity and related discussions of genetic technologies was to foster student understanding of the basic principles of DNA technology and the variety of applications it has in modern society.

As an invitation to the unit, we started with a role-play activity. Seven members of the biology class volunteered to take on the roles of crime scene investigators and suspects. These volunteers presented a crime scene report to the rest of the class, as it is indicated in Figure 1.

Following the presentation of this report, students were divided into small groups to brainstorm ideas for solving the crime. During the small group discussions, students were given appropriate prompts to think about specific possibilities. Each group generated a list of possible actions to take. Then, the entire class convened together to compile a class list. Some of their suggestions included: Obtaining blood samples from each suspect; analyzing and typing the blood collected; extracting DNA from the blood cells of the suspects; subjecting the DNA of the suspects and crime scene evidence to gel electrophoresis; and comparing the DNA fingerprints for commonalities.

Student participation was encouraged by recording all their suggestions on the board. As a class, we examined this list and the information available in order to decide what steps should be taken and the timeline that should be used to complete the investigation. By working together to devise how investigations are carried out, students gained a sense of ownership in their education. All students were actively involved in deciding what actions should be taken to solve the crime. They were not merely given a set of written procedures to follow.

Confidential

Case of the Crown Jewels: Police Report

My name is Friday, Joe Friday. I work with my assistant, Dee Enae. Together, we keep the city safe. We're detectives. It was early Thursday morning. We were already on the scene. Officer Ligase approached me, "We haven't got much for you, Friday. It was a clean job. Not a print. Whoever it was got in and out with the jewels without a trace." "There is no crime without its clues. They're here. We'll find them," I replied. Just then Dee Enae yelled, "Friday, over here." "What is it Dee?" I said. "Some blood on the sill. Looks like our thief cut himself on the broken glass." "Good work, Dee. Let's see what the lab can do with this." Back at the crime lab, the messenger R. Renee gave the package to technician Edna N. Zime. N. Zime opened the package and took out a plastic bag marked Crime Scene. She began extracting the DNA from the blood sample in the bag. Because the sample was so small, she had to amplify the DNA using the polymerase chain reaction. Meanwhile, Dee Enae and Friday had narrowed the suspects to four people.

Suspect #1

Pockets Peterson: A widely known and successful crime chief. Peterson had been known to brag that he could get by any security system. He said he would prove it by some day taking the crown jewels. No stone has been known to have higher security.

Suspect #2

Cruella "the Cat" Blanchard: Owns the largest private collection of precious stones in the world. She has offered millions of dollars for them. Having been a member of the prestigious ninja swat team, she has the talent and guts to pull off such a crime.

Suspect #3

Professor Angstrom: Past curator of the museum that housed the Crown Jewels. He was recently fired from his job and replaced by the boss's niece. His motive may be revenge.

Suspect #4

The Resident Scientist: Credited for discovery of the Jewel. She claims it is rightfully hers. As Edna's lab assistants, each one of you will receive an envelope containing a DNA sample obtained either from the crime scene or from one of the suspects. Each person is to follow the instructions in their envelope. Work only on your DNA sample.

Figure 1. The Crime Scene Report.
(Developed by CityLab: A Biotechnology Learning Laboratory for students and teachers; Boston University School of Medicine, 1993, © Trustees of Boston University. Reprinted with permission.)

Solving the Crime: Students as Forensic Scientists

The second component of the unit involved students working collaboratively in groups of three to formulate hypotheses based on the evidence and profiles of the suspects. Students were given envelopes containing paper DNA samples. In the days prior to this part of the unit, students had practiced the methods involved in Polymerase Chain Reaction (PCR) process and learned about the role of restriction enzymes. They had already used the method to solve a paternity case. In this section of the unit, the groups utilized their prior knowledge to cut the DNA into base-pair fragments and created a simulated paper gel lane. At the closure of the pre-lab, students were asked to write what they had learned from the activity in their journal, focusing on why they thought DNA restriction analysis was or was not important for them to learn about. A few student responses to this journal entry question are provided in Figure 2.

I think DNA technology will have a direct impact on how we live in the future. I believe that eventually we may be judged by our genetic code like in the movie Gattaca. For example, you will go for an interview and they will take a blood sample to analyze your DNA and give you the job based on your genetic code.

I think, it is important to know about DNA because of insurance purposes. I believe that insurance carriers may not provide coverage, if your DNA is flawed in anyway.

I think that society may use the technology in the future to create genetically perfect humans. In turn, this will cause a new form of prejudice, because those people who are genetically flawed will be looked down upon and exiled as a result of their genetic code. I think that the future will lead to a society like that in the movie Gattaca.

Figure 2. Sample Statements from Student Journals

Prior to starting the wet-lab portion of the unit, we discussed their journal entries from the pre-lab. Students were given the opportunity to share their thoughts. After all students discussed what they had learned, we reviewed by conducting another role-play activity. The students who volunteered were given colored cards with either A, T, C, or G printed on them. They lined up in a specific order and linked arms. As a class, we then reviewed their knowledge of the DNA molecule using questions, such as what are the basic units that make up the DNA molecule, what did each student holding a card represent, what was different about my DNA when compared to theirs, how can the arrangement of nucleotide bases be used to solve a crime, and what determines where restriction enzymes cut? Following the review, students began the wet-lab portion of the unit.

During the wet-lab students prepared agarose gel and a DNA electrophoresis buffer. Students then practiced their pipeting techniques using a dye that they loaded into a prepared petri-dish containing the gel. Upon completion of the practice activity, they centrifuged their DNA samples, so that they could easily extract it with their micropipettes to load into the gel chambers. We used DNA purchased from a local biological supply company for the lab. Once the DNA was loaded into the gel, they submitted it to an electric current and observed as the DNA fragments migrated to the other end of the gel lane. Students then compared each suspect's DNA fingerprint with that of the crime scene DNA. They were able to find a match among the suspects. After completing the gel electrophoresis part of the experiment, students used simulated blood to type the suspects. They compared the suspect's blood type to that of the blood found at the crime scene.

For many of our students, it was the first time they used actual DNA, electrophoresis chambers, and a centrifuge. Students learned a great deal from these experiences. We wanted them to visualize and experience how forensic scientists use modern DNA technology to solve crimes. By analyzing the DNA, they were able to obtain a meaning of the process of DNA fingerprinting and gain an appreciation for the use of this technology in modern society. The excitement was evident on the student's faces, as they observed their DNA samples run through the gel.

At the conclusion of the wet-lab, students discussed and interpreted their results in their small groups. In the groups, students had the task of explaining which suspect was guilty of the crime and how they determined this information to

be correct. Each group had to decide the value of this method and its use in a court of law. They also had to develop a set of questions that they would ask a forensic scientist, if the evidence was being used against them or a client that they represented.

Understanding Genetic Technologies: Assessment of Student Learning

Since the main focus of the "crime scene investigation" activity and related discussions of genetic technologies was to foster student understanding of the basic principles of DNA technology and the variety of applications it has in modern society, we assessed student learning by using a questionnaire, shown in Figure 3, as a pre-and post-test. This questionnaire was developed and provided by Dana Haine of "DESTINY, The Traveling Science Learning Program" at University of North Carolina, Chapel Hill, North Carolina, USA.

A. COGNITIVE ITEMS

Please respond by identifying whether each of the following statements is TRUE or FALSE. If you are uncertain or don't know the answer, please write UNCERTAIN.

1. Restriction enzymes cut DNA at random nucleotide sequences.
2. DNA is the hereditary material found in cells.
3. Gel Electrophoresis is a lab technique used to separate DNA molecules based on differences in charge.
4. Identical twins each have a unique genetic profile or "DNA fingerprint."
5. DNA fingerprinting is a technique that can be used to determine paternity.
6. To clone a gene means to make many identical copies of it.
7. A karyotype can reveal if a person has any chromosomal abnormalities.
8. A transgenic organism does not contain foreign DNA.
9. Genes are located on chromosomes.
10. Translation is the process of copying DNA into mRNA.
11. Genes code for proteins.
12. Gene Therapy is the insertion of normal genes into cells to correct genetic disorders.
13. Amniocentesis allows for prenatal diagnosis of genetic disorders.
14. Scientists know how to genetically modify organisms.
15. The human genome project led to the sequencing and mapping of the entire human genome.
16. Gene splicing refers to the technique used to join different fragments of DNA into a single molecule.

B. OPINION ITEMS (Included in the post-test only but ask for opinion AFTER and BEFORE the completion of the unit.

Please give your opinion about each of the following items. Choose whether you agree, disagree, or are uncertain about each of the following.

a. I am interested in DNA technology and its applications AFTER completing this unit.

b. I was interested in DNA technology and its applications BEFORE completing this unit.

c. I feel confident answering questions about DNA technology AFTER completing this unit.

d. I felt confident answering questions about DNA technology BEFORE completing this unit.

Figure 3 (continued)

e. I feel confident at discussing issues related to DNA technology with my friends and family AFTER completing this unit.

f. I felt confident at discussing issues related to DNA technology with my friends and family BEFORE this unit.

g. AFTER completing this unit, I have knowledge of DNA technology and its applications.

h. BEFORE completing this unit, I had knowledge of DNA technology and its applications.

Figure 3. Questionnaire Used for Pre-Post Assessment

While the results of the pre-post assessment indicate noticeable gains in only a few "cognitive items," specifically items 2, 5, and 9 as indicated in Table 1, their interest in DNA technologies and confidence to discuss their applications in modern society seems to have improved as a result of participation in this unit (Table 2). Although the results presented in Table 1 are not an impressive indicator of the impact of this unit on student understanding of some of the basic principles associated with DNA technologies, their oral presentations of how they solved the "case of the crown jewels" indicated a sound understanding of the processes involved in DNA fingerprinting and the application of these processes in identifying the perpetrator of the crime. This explains the positive results obtained on the "opinion items" included in the post-test questionnaire shown in Table 2.

Table 1
Pre-Post Assessment Results: Cognitive Items

Statement Number	Pre-Test			Post-Test		
	True	False	Uncertain	True	False	Uncertain
1	8	5	11	24		
2	20	5		24		
3	10	2	12	24		
4	10	8	6	15	9	
5	10	2	12	20	4	
6	15	9		15	9	
7	4	8	12	6	8	10
8	2	4	18	2	4	18
9	20	4		22		2
10	20	4		22		2
11	15	8	1	15	8	1
12	2	4	18	2	4	18
13	4	8	12	6	8	10
14	18	2	4	18	2	5
15	20		4	21		3
16	3	10	11	4	7	13

NOTE: The numbers in columns titled True, False, and Uncertain, indicate the number of students who chose that particular response for a specific item in pre-and post-test.

Table 2
Assessment Results: Opinion Items

Statement ID	Agree	Disagree	Uncertain
a.	20		
b.	8	6	10
c.	20		4
d.	8		16
e.	20		4
f.	8		16
g.	22		2
h.	10	4	10

Conclusion: Cognitive and Affective Impact of Connecting Science, Technology and Society

We set the stage for interaction by using role-play, class discussions, and inquiry-based laboratory investigations to introduce students to the topic of DNA and the advances of DNA technology. Students demonstrated their understanding by communicating their knowledge orally (as they explained who the perpetrator of the crime was, based upon their investigation) rather than merely responding to a set of written test questions. Students used logic and reasoning to solve a crime as they worked in collaborative teams to carry out the investigation, which had direct relevance to real life. All students participated in the activities with enthusiasm and used inquiry techniques to unravel the mystery.

Upon completion of the unit students were asked to evaluate the effectiveness of the activities. Many commented that they enjoyed the class much more than their traditional classes. They felt they had learned more as a result of the hands-on/minds-on approach. They also commented that they enjoyed working in groups and felt that they were part of a scientific team. Most importantly, as reflected by the statements in their journals shown in Figure 2, and responses to the 'opinion items' on the post-test questionnaire shown in Table 2, students developed a sound understanding of the connections between the knowledge, associated technologies, and societal implications of DNA. As a result, students gained an appreciation for the usefulness and application of the science they learned in school.

Appendix

Selected On-line Resources for Classroom Instruction in Genetic Technologies

www.pbs.org/wgbh/nova/sheppard/analyze.html

www.discoveryschool.com

www.accessexcellence.org

www.koshlandscience.org

www.swbic.org/education/crime.php

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