Focus on Forensics

Teaching science in a forensic context

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Introduction

Teaching science in a forensic context has been gaining in popularity right around the world for well over a decade. The idea is that topics that might seem dry and uninteresting can be presented in a more exciting way to help engage students and get them involved.

Mysteries and "who-dun-its" have always been popular as books, movies and TV shows, but the inclusion of forensic science in TV programs such as "CSI" has increased students' awareness of how science can be used to evaluate evidence and solve a mystery. Any "real life" forensic scientist will tell you that the TV depictions stretch the truth to some extent, but in most cases, what is shown is at least based on reality.

This workshop aims to show some secondary science topics that can easily be adapted to a forensic science context.

Gel electrophoresis

Blood Typing

Microbiology

Fibre identification

Gel Electrophoresis

Gel electrophoresis has become the standard technique for separating mixtures of charged molecules such as proteins and fragments of DNA. An electric field provides the motive force to drive the charged species through the gel. By selecting the right combination of electric field strength, gel type and gel concentration, complex mixtures can be separated, and the individual components can even be collected for further analysis.

Electrophoresis is used in forensic science to compare samples of DNA collected at a crime scene to DNA from one or more suspects. A match can implicate a suspect with a very high degree of confidence. Electrophoresis of proteins is also used in forensic tests to expose food substitution fraud such as when a cheap type of fish is passed off as barramundi.

Electrophoresis of proteins can be problematic in a classroom setting because high voltages (up to 300V DC) and dense polyacrylamide gels are required. However, electrophoresis of DNA is quite easily done these days with 0.8% agarose gels and TBE buffer running at 60-100V DC. Unless you have very sophisticated equipment, it is not a simple matter to attempt collection, purification and digestion of DNA with restriction enzymes. A more feasible approach is to purchase pre-digested DNA that is ready to

load and run on a gel. Various DNA ladders and markers are available that can be arbitrarily labeled “crime scene”, “victim”, “suspect 1” and “suspect 2”. Take care that the “crime scene” DNA is the same as one of the suspects in order to ensure that the guilty party is identified.

A quick and low cost simulation of a DNA electrophoresis experiment can be run using water soluble dyes. Instead of agarose, a 1% plain agar gel can be used, and instead of TBE buffer, a 0.1% $NaHCO_3$ solution can be used. Mix each dye solution with glycol or a concentrated sugar solution to assist loading.

Blood Typing

Early in the 20th century, the ABO blood typing system was discovered by an Austrian scientist called Karl Landsteiner. He was also involved in the later discovery of the Rh factor blood grouping system.

The main use of blood typing tests is to ensure safe transfusions, but it can also be used as a quick test in forensics to screen certain suspects and rule them out. For example, let us suppose that a forensic examiner tested blood that had been collected from a crime scene and found it to be type O+. A short time later, the police arrested a suspect found in the area with a cut on his arm. The examiner tested the blood type of the suspect and found it to be A-. Since the blood types do not match, the examiner can conclude that the suspect did not leave his blood at the scene.

ABO typing is based on the presence or absence of antigens on the surface of red blood cells, and the presence or absence of antibodies in the blood plasma. Red blood cells may contain type A antigens, or type B antigens, or both together (type AB), or neither (type O). As a corollary, blood plasma contains particular antibodies to complement the antigens on the red blood cells. The purpose of the antibodies is to mount an immunological response to foreign antigens if they should appear in the blood. Type A blood has anti-B antibodies, type B blood has anti-A antibodies, type AB blood has neither anti-A nor anti-B antibodies, and type O blood has both anti-A and anti-B antibodies.

As well as the A and B antigens, red blood cells may or may not have Rh factor antigens on the surface. Blood that has Rh factor antigens is described as Rh+. Blood that does not have the Rh factor antigen is Rh-. People with Rh- blood can develop anti-Rh antibodies if they are exposed to Rh+ blood.

The four ABO possibilities and the two Rh possibilities give a total of eight possible blood types under these systems:

O-	no antigens
O+	Rh antigen only
A-	A antigen only
A+	A and Rh antigens
B-	B antigen only
B+	B and Rh antigens
AB-	A and B antigens
AB+	A, B and Rh antigens

Blood typing involves placing three drops of blood on a white plate and adding one drop of anti-serum to each as follows:

> To the first drop, add one drop of serum containing anti-A antibodies. If the droplets mix without clumping, the blood contains no A antigens. If clumping occurs, the blood contains A antigens.

To the second drop, add one drop of serum containing anti-B antibodies. If the droplets mix without clumping, the blood contains no B antigens. If clumping occurs, the blood contains B antigens.

To the third drop, add one drop of serum containing anti-Rh antibodies (also called anti-D antibodies). If the droplets mix without clumping, the blood contains no Rh antigens. If clumping occurs, the blood contains Rh antigens.

The ready availability of simulated blood and anti sera has now made realistic but totally safe blood typing experiments easy to perform in school laboratories.

Microbiology

One of the easiest ways to present microbiology in a forensic context is to simulate a food poisoning situation. For example, students are told that a large number of guests at a function became ill, and food poisoning is suspected. Their task is to test the food and/or drinks in order to decide which item (or items) was responsible. This situation is encountered too often in real life. Consider this report from the US:

> *America's fruitless search for the source of a nationwide salmonella outbreak that has infected more than 800 people and hospitalised 107 has widened beyond the prime suspect, tomatoes. Weeks after declaring tomatoes suspect, the Food and Drug Administration is believed to have included in its investigation jalapeno chillis, spring onions and coriander, ingredients often mixed with raw tomatoes. Tomatoes have not been cleared, a spokesman for the FDA stressed yesterday, and remain the "lead suspect". "We go where the science takes us," he said. The outbreak of "salmonella saintpaul" has sickened people in 36 states, especially in Texas and New Mexico, where half the infections have occurred. The most recent confirmed episodes were on June 20. It is the most serious food-borne illness episode in the US since three people died in 2006 after consuming spinach tainted with E. coli. FDA investigators have been unable to trace the source of infection despite visits to farms, food packers and related firms. "We have taken tomatoes for testing and done extensive sampling of water in irrigation wells, storage containers, packing houses ... essentially every point along the chain where contamination might have occurred," the spokesman said. He said investigators had to rely on infected people recalling things which were not very memorable, such as what they ate last week. "Salmonella is (a) highly mobile bacteria that easily travels the path from origination through to distribution, to infection," he said. "Like any investigation, the trail gets colder with each passing day."*
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> Reported in ***The Age***, 4th July 2008

There are a couple of ways to present this activity, but the most realistic method is to give the students several samples (water is easiest) that have been recovered from the suspect kitchen, one of which has been "spiked" with a small amount of *E.coli* broth. Colour each sample with a few drops of food dye to differentiate them. You can run this activity as a simple microbiology exercise by having students test each sample on standard Aerobic Count Petrifilm plates to identify the sample containing the unusually high number of microorganisms.

You can extend the work in several directions. For example, test the high count sample on a Coliform or *E.coli*/Coliform Petrifilm plate to confirm the type of organism

responsible for the contamination. Perform serial dilutions to enumerate the microorganisms present.

You can also add to the mystery by having a second spiked sample, but this time use a non-coliform such as *Staph albus*. Students will identify two samples with high bacterial contamination, but only one due to a coliform. They can then be tasked with correlating what guests drank with who became ill to determine whether it was the coliform sample or the non-coliform sample or both that caused the outbreak of food poisoning. To add even more intrigue, have students analyse how much of each drink was consumed by the guests who became ill.

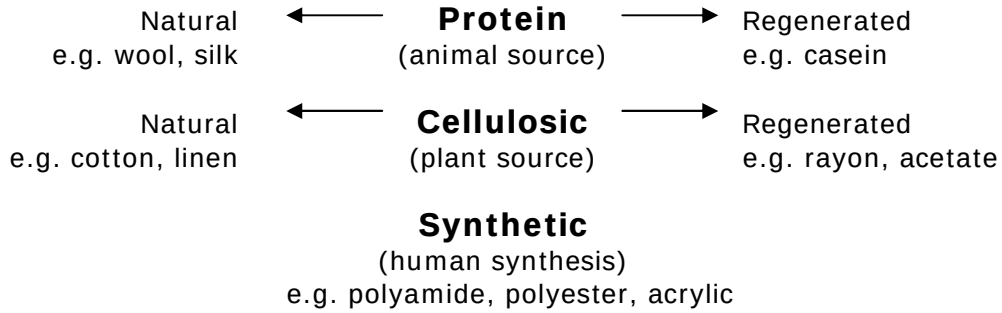
This exercise can lead in to a good discussion about personal hygiene and food safety.

Fibre Identification

Fibre identification is always a popular laboratory activity and ideal for presenting in a forensic context. Provide students with samples that have been gathered as "evidence" and have them link the samples to suspects in order to identify the guilty party.

The important key to a successful fibre identification exercise is to use samples that have not been dyed and are free from resin finishes that can mask the essential characteristics of the fibres being examined. For introductory activities, it is also a good idea to use pure samples rather than mixtures or blends.

Fibres can be classified according to their composition as follows:



A burn test is the easiest way to make the initial classification. Fibres composed of proteins smell like burning hair and tend to blister and char. Cellulosic fibres smell like burning paper and leave a slight residue of fine grey ash. Synthetics tend to have a smell like burning plastic and usually (but not always!) melt as they burn.

As well as honing skills in experimental design, fibre identification is a great way to have students learn how to prepare slides and gain skills in microscopy. To identify unique visual characteristics , they will need to examine fibres at 400x magnification. This will lead to improved sample preparation, the ability to focus with a shallow depth of field, and the ability to recognize artefacts such as air bubbles.

Unique visual characteristics of common fibres include:

Cotton	lumen and ribbon-like convolutions
Linen	bamboo-like markings across the width
Rayon	striations along the length
Wool	overlapping scales on the fibre surface
Silk	rod-like filaments
Synthetics	rod-like filaments that may contain specks due to the presence of delustrant (TiO_2 particles)

More Resources

Many publishers and equipment manufacturers supply products that are designed to help teachers present forensic science lessons. For example:

The Crime Fighter

Written and published in Australia, this 24-page book is ideally suited to 5-10 week units for years 7-10. It describes activities such as finger printing, making footprint plaster casts, and using chemistry to identify colours in black ink. A Teacher's Guide is included. Southern Biological product code = BK70.20

Forensic Science Teacher's Collection

Topics ranging from osmosis to the polymerase chain reaction are presented in the context of a crime or mystery for students to solve. Investigative teams are responsible for finding background information in their laboratory guides, designing their experimental set-up, interpreting data and preparing results for presentation as would be done by a forensic scientist. This item consists of

- a Teacher's Manual containing case descriptions, selected answers, material lists and tips
- a Student Guide (black line master) with information in textbook format for students to understand and complete the exercises.

Southern Biological product code = BK70.60

Detective Science

This 114-age book contains 40 activities for years 7-10 involving searching for evidence, gathering clues and discovering how science helps solve mysteries. Southern Biological product code = BK70.35

Crime Solving Science Projects

This 128-page book describes experiments on fingerprint analysis, document counterfeiting and forgery, and evaluating trace evidence. Southern Biological product code = BK71.40

Electrophoresis Kit

This is a reliable self-contained experimental kit that simulates the use of DNA in forensic investigations. Students cast agarose gels, load pre-digested DNA and perform electrophoresis. The banding patterns of the DNA in the gel are used to compare the DNA profiles of two suspects with the evidence DNA. The power supply is not included, but 9V batteries may be used. Southern Biological products codes = G3.00 (Demo kit), G3.00CK (Classroom kit) and G3.00CKRK (Classroom kit refill).

Web sites

There are also many web based resources available to teachers. For example,

Texas Instruments: www.tiforensics.com

National Institute of Forensic Science: www.nifs.com.au

Use a search engine to track down more sites that can help give you ideas.

Conclusion

Whether you are presenting a one-off practical exercise, or planning a multi-week program of activities such as described in the appendix, framing the activity in the context of a forensic investigation is guaranteed to spark excitement and interest amongst your students. What seemed like a dull and uninteresting lecture can be transformed into an engaging topic that can involve everyone in the class. Forensic science is also a context that can be adapted for all ages, from primary to senior secondary.

Appendix

At the NSTA conference in April 2006, I was able to hear an account of a very successful forensic science program run by teacher Eric Rude at Pocatello High School in Idaho USA. He developed a 9 week course for middle school students who would not have been able to complete a traditional science course. His aim was to give them a "science credit" by having them learn a range of methods and techniques, as well as understand the science behind each activity.

He stressed that it is important to vary the details of the "crime" each year to add to the interest and anticipation of students who are about to start the program. He also compounds the depth of the mystery by setting two objectives - identify the criminal ***and*** the victim.

Examples of tests:

Fingerprints

Metal objects (e.g. a butter knife) collected at the crime scene can be tested by exposing to super glue fumes under a plastic cover in a fume cupboard.

Finger prints on the sticky side of adhesive tape can be "developed" by immersing in a solution of crystal violet.

A commercial finger printing kit can be used if resources permit, but sometimes there are more learning outcomes with "home made" tests.

Suspects' prints can be obtained with an ink pad.

In each case, the finger prints can be scanned and enlarged to make examination easier.

Soil

Soil can have various additives included to help narrow down the range of suspects. For example:

- Add $NaHCO_3$ powder to increase the pH
- Add fluorescent GlitterBug powder that will show up under UV light
- Add iron filings that will respond to a magnet
- Add objects such as shell grit, coloured sand, pine needles, seeds etc that can be associated with a particular place or activity that might be linked with the victim or the criminal.

Students carry out tests such as sieving to provide qualitative and quantitative data. Test with a few drops of HCl solution to see if there is a reaction due to $NaHCO_3$ or metal fragments. Measure the pH of an aqueous extract. Measure the settling rate by using a spectrophotometer or colorimeter and determining the time for light transmittance to drop. Measure the density gradient in a home-made densitometer consisting of a small cylinder containing 1-2mL of five different liquids such as corn syrup, water, glycerine, corn oil and iso-propanol.

Blood Typing

Carry out ABO blood typing on synthetic blood "found" at the scene. Does it belong to the victim or the criminal, or could it be either? Also carry out typing on synthetic blood samples "taken" from suspects. Does blood typing allow any suspects to be eliminated?

Fibre Identification

Use microscopic analysis to identify fibres found at the scene and then link them with the victim and suspects. Compare the fibres to descriptions of clothing in missing persons reports to assist in the victim identification process. Use fibre results to confirm or eliminate some suspects. Perhaps include animal hair to link the victim or a suspect to an animal such as a dog or cat.

It is also possible to use a laser pointer to estimate fibre diameter from an interference pattern.

Bone Analysis

Use diagrams and cardboard cutouts of bones to estimate the height and gender of the victim. Use the results with other data to identify the victim conclusively.

Records

The students must keep an accurate record at each stage of the investigation. This can include lists, descriptions, diagrams, pictures and photographs, tables of results, graphs, calculations, and deductive reasoning leading to conclusions. It should also include information about the methods used.

Some practicalities

Suspects are always teachers or other staff at the school. The program concludes with an "arrest" of the guilty party by the students. Before they can arrest their suspect, students must obtain an "arrest warrant" from their coordinator by justifying their case. This is a form of oral exam which includes the written details of their test results and conclusions. If necessary, the coordinator will guide the students to check their data before issuing the warrant. In other words, they have to arrest the right staff member!

Students collect evidence from the crime scene at the start of the program, but, to minimize downtime, evidence gathered from suspects is provided in sealed bags.

Ideally, the crime scene should be an area that can be locked up for the period of the investigation to conserve the evidence, e.g. shed or storage room. Even for outdoor crime scenes, it is useful to have a secure room where evidence can be safely stored after it has been collected, bagged and labeled.

For more information, visit Eric's forensic web site at:

http://web1.d25.k12.id.us/home/staff/rudeer/forensics.html