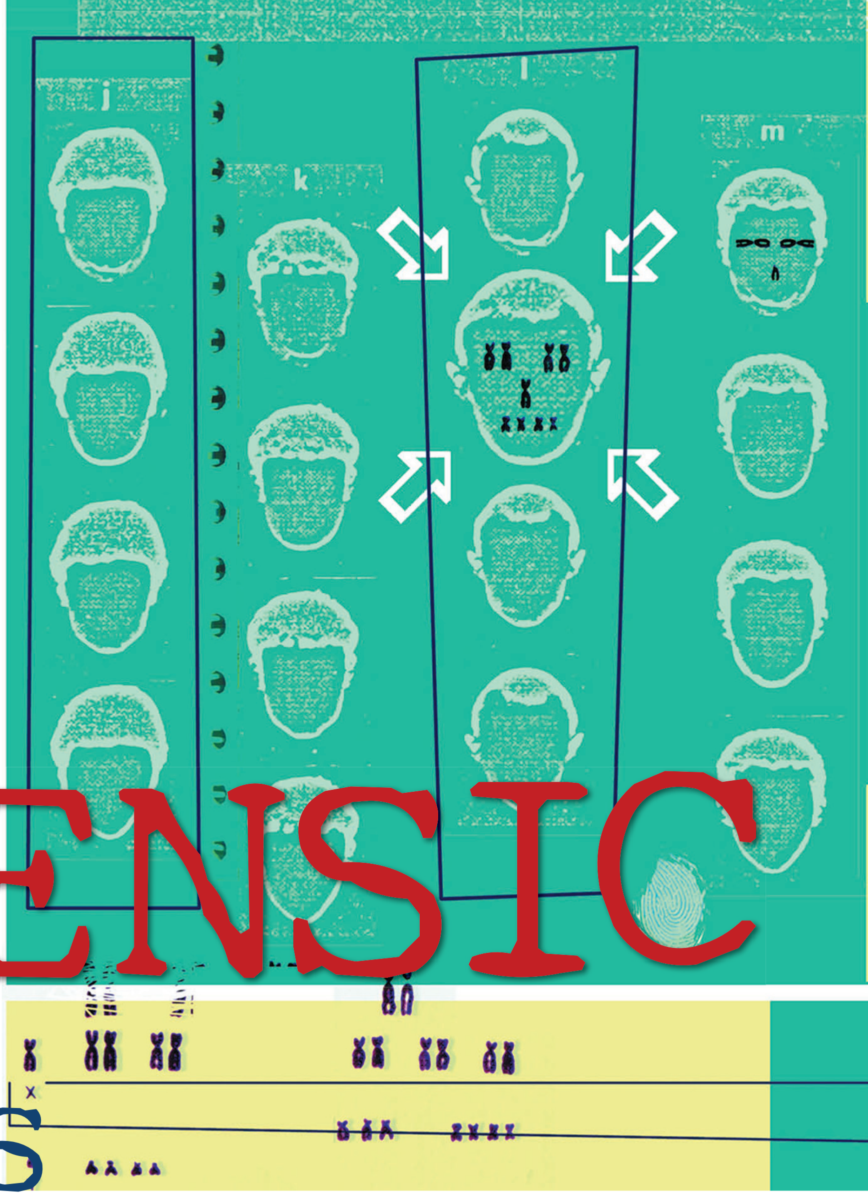


Helping students think like scientists about authentic problems

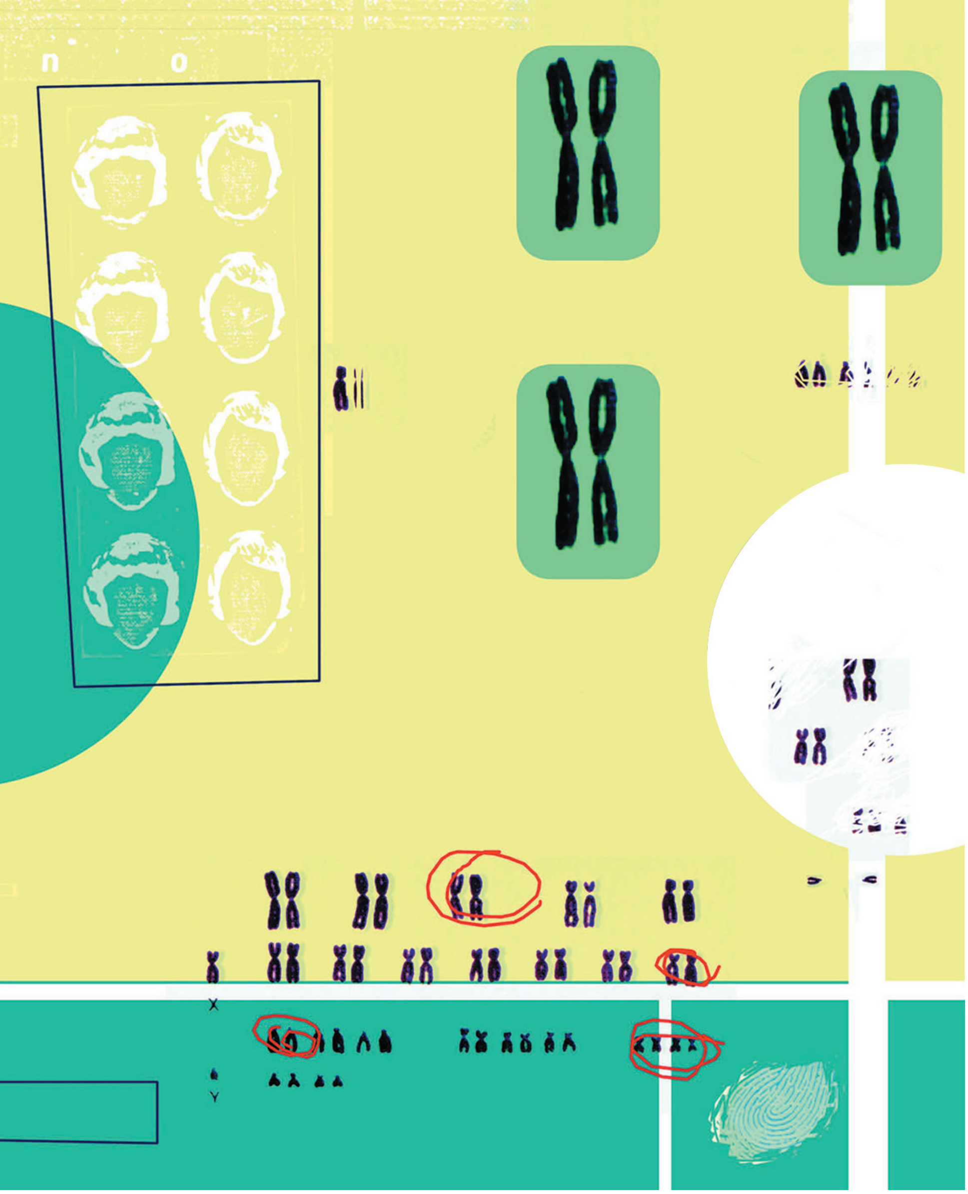
USING FORENSIC SCIENCE PROBLEMS AS TEACHING TOOLS

Kanesa Duncan and Toby Daly-Engel

The desire to observe and understand the natural world is strong in young children, but high school students often consider science irrelevant to their daily lives (Young 1997). Therefore, as teachers of older age groups, we constantly struggle to engage students in scientific exploration so they can master concepts and appreciate the nature of science. By providing an air of mystery and glamour, forensic science engages even reluctant students in the scientific process and helps them think like scientists about authentic problems—one of the ultimate goals of science education (Williams et al. 2004).

Recent technological advances have made forensic science extremely important in the criminal justice system (Asplen 1999; Friedman 1999). Television shows such as *CSI: Crime Scene Investigation* have popularized this science and created a pulse of excitement among the general public and our students. The negative repercussions of popularizing forensic science are many, including increased expectations of jurors (Willing 2005; Deutsch 2006) and unrealistic, romanticized views of science itself. However, the popular media has also provided educators with an opportunity to exploit the increased scientific curiosity among students.

Forensic courses and curricula are being assembled at a rapid rate, and many high schools now teach courses in forensic science. In fact, at the 2006 National Science Teacher's Association (NSTA) Conference, at least 21 events (talks, field trips, or workshops) dealt with forensics (see *www.nsta.org/conferences*). However, many schools do not have the ability to dedicate an entire se-



mester or year to a forensics course. The purpose of our project, therefore, was to use the umbrella of forensics to teach typical biology concepts and skills in a setting that students would find engaging. We used the *CSI* television show to set up a "myth-busting" environment in the classroom and to enable us to investigate the relationship between popular media and our students' attitudes about science.

Science disguised as a whodunit

The forensics unit was taught in partnership with a National Science Foundation Graduate K–12 fellow—a graduate student in the natural sciences working to develop teaching skills and provide professional development for the teacher; this fellow was a molecular biologist but not a forensic expert. The students consisted of two 12th-grade biology classes (52 students) at the University of Hawaii Laboratory School (UH Lab). Students attending UH Lab (a public charter school) represent a cross-section of Hawaii's education population, including a full range of ability levels (stanines 2–9), socioeconomic backgrounds, and ethnicities. Students in this program have taken marine science, physics, and chemistry. This was their first biology course. Students took a pre- and post- evaluation designed to assess their opinions about science, scientists, forensics, and popular forensics shows such as *CSI* (Figures 1–3, p. 40).

Introduction

The forensics unit was introduced with a *CSI* episode and concluded with the critique of a second *CSI* episode. The first episode, "Harvest," dealt with a bone-marrow transplant, which suggested that DNA in the blood of the transplant recipient caused it to match the DNA of the donor. The second episode, "Bloodlines," dealt with a congenital chimera, which is a person who is born with more than one distinct cell line (more than one set of DNA). We screened our *CSI* episodes to avoid overly graphic scenes and had students' parents sign consent waivers. Teachers should note that many forensic television shows deal with mature material, including violence, rape, murder, and child molestation. Despite the effectiveness of the shows in engaging our older students, some content would be inappropriate to use with younger age groups, and care must be taken when selecting episodes, even for older student groups.

Lessons

The lessons within the unit were composed of concepts already planned for the biology course (Figure 4, p. 42) but were couched within a forensic context. [**Safety note:** Students were versed in lab safety and the special precautions and implications of forensic science.] For example, we discussed the effect of false-positive tests and the need for standard lab protocols when results will be used for criminal prosecution. The connection to judicial punishment made the consequences of poor lab practices more apparent. Prior to the content activities, students used shaving cream as a mock bodily fluid to assess their glove-use practices, and we discussed ethical issues relevant to science in criminal investigations.

We began the unit with a blood-typing lesson, which uses the reaction of milk protein and vinegar (Kalumuck 2005) to simulate the reaction between antibodies and antigens in blood. Students were then presented with a problem: three same-sex babies (two fraternal twins and a single child) were mixed up during a hospital fire. Could parental and baby blood types be used to construct a pedigree and determine which babies belonged to which

FIGURE 1

Postprogram data from all students.

Students were asked to rate their experience in the forensic program. Error bars show standard deviations. The agreement scale is scored from 1 (strongly disagree) to 5 (strongly agree); 3 is neutral.

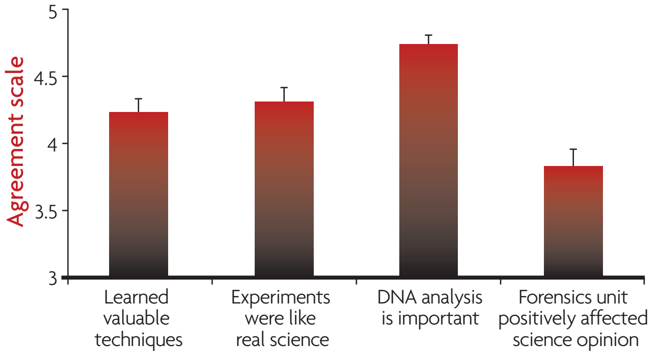


FIGURE 2

Preprogram data from students who watch *CSI* at least twice a month.

Students were asked to respond to statements as to why they watch *CSI* and how they feel the show affects their perception and knowledge of science. Error bars show standard deviations. The agreement scale is scored from 1 (strongly disagree) to 5 (strongly agree); 3 is neutral.

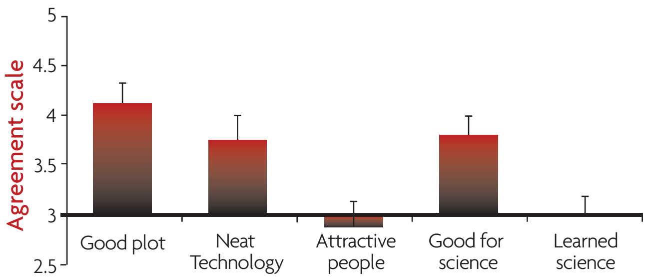
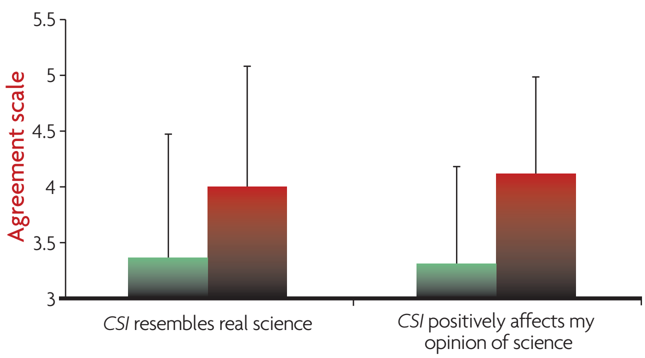


FIGURE 3

Pre- and postprogram comparison of students who watch *CSI* at least twice a month.

Students were asked to respond to statements about the resemblance of *CSI* to real science and the effect of *CSI* on their opinion of science. Green bars indicate predata and red bars indicate postdata. Error bars show standard deviations. The pre- and postdata is significantly different in both cases (paired t-test, $p < 0.001$). The agreement scale is scored from 1 (strongly disagree) to 5 (strongly agree); 3 is neutral.



parents? Our previous unit dealt with Mendelian genetics and this served as an excellent review. Students were then given a quiz on Punnett squares and inheritance, using practical problems such as organ transplants, blood transfusions, and crime-scene evidence.

Our next topics included the genetic code and the structure of DNA. Some of this information was delivered by direct lecture and class discussion, and we made comparisons between the genetic code and cryptology, allowing students to "crack" codes on their own. Students also extracted DNA from a kiwi fruit. A salting-out procedure was chosen due to high yield of DNA and because the product is safe for students to touch (Kalumuck 2005).

Before moving on to forensic uses of DNA structure, students practiced laboratory techniques, pipetting colored water (food coloring) to investigate the effect of multiple measurements (i.e., multiple pipettings) on the accuracy of their final sample amount. Students then learned about restriction enzymes, their relationship to DNA structure, and the practice of using Restriction Fragment Length Polymorphisms (RFLP) to individualize samples. Individualization is an integral part of forensic science because it allows identification to the exclusion of other possibilities. We taught students about the use of gel electrophoresis to separate particles using a chihuahua–sumo wrestler example (Who would get from one end of a crowded subway car to the other the fastest? The chihuahua because it can run between the people packed in the car, similar to the faster migration of small particles through an agarose gel). Students were given practice cards of simulated RFLP runs and crime problems to solve (we used DNA Fingerprinting—Electrophoresis at work, *www.flinnsci.com*). Then students were presented with the problem of a stolen prized parakeet. They used RFLP analysis and electrophoresis to match the suspects with the DNA evidence collected from the crime scene and wrote a formal report detailing their efforts and findings (we used the Forensic DNA Fingerprinting Kit, *www.explorer.bio-rad.com;* similar kits are available from other manufacturers).

Our final in-class lessons dealt with mutation and the realization that mutations must be present to create the differences that are used to individualize crime-scene evidence. We extended this idea to population biology and evolution. Students learned about the processes of polymerase chain reaction (PCR) and DNA sequencing. Students manipulated DNA sequence information obtained from Hawaiian *Drosophila* flies to make evolutionary inferences (Olson 2004) and discussed rates of evolution and the ways that various organisms exchange DNA. Students then experimented with plasmid transfer between bacteria, which was visualized as green fluorescent protein (we used the pGLO Bacterial Transformation Kit, *www.explorer.bio-rad.com;* similar kits are available from other manufacturers).

Real-life situations

To extend the activities, concepts, and skills outside the context of crime-scene forensics, students were exposed to three real-life situations. The first of these was a tour of a molecular marine lab at the Hawaii Institute of Marine Biology. Here, students spoke with environmental forensic scientists and marine biologists who work in a different context but use tools similar to those the students had been practicing with. We were also fortunate to have Lee Goff, a forensic entomologist and chair of the Forensics Department at Chaminade University, talk with our students and share photos of how insects are used in solving crimes and determining time-of-death (Goff 2000). His presentation helped stimulate discussions of ecological succession and biodiversity. Our final excursion was to the morgue and pathology unit at Queen's Hospital where students not only observed the forensic process but also were introduced to body systems and the effects of disease and lifestyle on these systems, an excellent transition into our body-system unit.

Extending the forensic unit into other aspects of biology was an important education goal and the field trips and guest lectures were an effective means of accomplishing this. Although the specific opportunities described here may not be available for every teacher, there are many other options. We also spoke with the Medical Examiner of Honolulu, the Scientific Investigation Section of the Honolulu Police Department, and the Honolulu District Court, all of which have programs already in place for student tours and/or in-class guest lectures; this is probably true in other locations as well. Adding such components to the forensic unit helped provide a sense of authenticity and demonstrated potential career opportunities to students.

Creating a sense of authenticity

Partnership programs and problem-based learning scenarios that involve students in scientific research are effective because they help students understand the realities of science by making them an active part of the scientific process (Baumgartner, Duncan, and Handler 2006; Handler and Duncan 2006). Although it is not always possible to involve students in a real-world research project, a realistic research experience can be created within the classroom. Part of our educational goal was to create a situation in the classroom that students would connect to as being "true to life." Forensics is an ideal setting within which to couch a simulated experiment because it is easy for students to identify the purpose behind solving a crime. They intuitively feel that it is important to find the answer and are motivated to solve the mystery.

Students had an overall positive response to the forensics unit. They generally felt that the curriculum was interesting, useful, and similar to real scientific experiments (Figure 1, p. 40). Students in our program were excited by forensics and engaged in solving the crimes we constructed. Moreover, they felt that their experiences were authentic; students viewed class labs as similar to experiments and procedures conducted by professional forensic scientists.

CSI publicity is good for science

Prior to the forensics unit, approximately half (49.5%) of our students reported watching *CSI* at least twice a month. These students reported watching *CSI* because of its interesting subject matter and "neat" technology. They also reported that the show provided positive and useful publicity for science, but that they did not learn science or scientific techniques from watching the show (Figure 2, p. 40). [**Editor's note:** The website for the *CSI* television show contains episode descriptions and interesting information about everything from gas chromatography to PCR *(www.cbs.com/primetime/csi/handbook)*.]

The ability to acquaint older students with the reality of science as a practice and a profession is particularly important, as older students (especially in their last semester of high school) are visualizing themselves in college and in careers rather than in class. Not only can they be harder to engage, they are mentally moving on to their adult lives. The forensics curriculum may help impart enthusiasm in science as a profession, especially among those students who are vague and undecided in their career choices.

Building a personal connection

Students who watched *CSI* at least twice a month reported a significant positive increase in their opinion of the television show after our forensics program. In other words, after participating in class, more students felt that *CSI* resembled real science and that it positively affected their opinion of science (Figure 3, p. 40). This was surprising; we had anticipated a negative shift in students' perception of the television show. In fact, part of the impetus of the forensics curriculum was for students to learn that laboratory analyses cannot be done instantaneously, a single person cannot possibly perform the large number of tasks shown on TV, and that stylish clothes and stunning personal beauty are not prerequisites to scientific investigation.

However, upon closer inspection of the curriculum and the student data, the positive attitude shift is understandable. In part, the *CSI* episodes we showed to students were biased; we preselected episodes that dealt with topics we covered in class. We also asked students to evaluate the shows for aspects similar to things covered in class or seen on their field trips (see student responses, Figure 5, p. 43). By practicing the molecular forensic techniques in class, students became highly attuned to those techniques when they saw them used during field trips and on *CSI*. In fact, during our field trip to the marine molecular facility, students were more excited to observe a skilled scientist rapidly pipetting DNA into a large gel than they were to feed captive sharks. This was surprising, but it demonstrates the incredible power of allowing students to form a personal connection to their study material. Students knew, from their own experience,

FIGURE 4

Concepts taught during the forensics program and their associated real-world context.

Please note that we have provided the brand-name of the materials that we used to make protocols easier to access. Multiple manufacturers make similar products. [**Editor's note:** Additional concepts taught, their associated real-world contexts, and how all of the concepts relate to the National Science Education Standards (NRC 1996) can be found with the online version of this article at *www.nsta.org/highschool#journal*.]

Concept or skill	Method	Forensic context	Real-world extrapolation	Assessment
Safety: Gloving-up	Shaving cream trial for proper use of gloves; "Wash" hands with shaving cream and remove gloves without touching cream	Contamination of evidence and safety of investigators	Scientific accuracy and safety	Self- and peer assessed by presence of shaving cream on skin
Blood typing and Punnett squares	Fake blood: using milk, vinegar, and water to simulate ABO blood types (Kalumuck 2005)	Basic skill and parentage assignment	Blood transfusions and organ donation	Laboratory worksheet with follow-up questions and practice Punnett square problems
DNA extraction (from kiwi fruit)	Basic salting out procedure using alcohol, salt, and soap (Kalumuck 2005)	Identification (individualization) of evidence	Gateway to molecular analysis of any type	Self- and peer assessed by observing resultant extracted DNA; Laboratory worksheet with follow-up question
Measurement and use of lab equipment	Using a pipette—mix 5 µL red water, 10 µL yellow water, 3.5 µL blue water = 18.5 µL total. Check accuracy by moving the 18.5 µL between tubes	Possible sources of contamination and experimental error	Use of tools (smallest measurement unit) and good lab practices	Self- and peer assessed by observing color changes
Restriction Fragment Length Polymorphism (RFLP)	Simulated RFLP results with mock crime scenario (DNA Fingerprinting—Electrophoresis at work, *www.flinnsci.com*) and a lab using restriction enzymes, stock DNA of a crime scene, five suspects, and a standard DNA ladder. We also used pipettes, water bath, and tubes (Forensic DNA Fingerprinting Kit, *www.explorer.bio-rad.com*)	Individualization and matching of evidence to suspects	Using standard and common genetic elements for identification and comparison	Formal report (in draft and final form) including assignment of suspect in simulated crime and evidence supporting the assignment of suspect
Polymerase Chain Reaction (PCR)	Lecture/discussion on amplification process with animation; Discussion on uses of PCR	Replication of DNA from trace amounts to amounts useful in genetic analysis	Necessary first step in majority of molecular processes	Quiz on DNA and replication
DNA sequencing and DNA fingerprinting	Lecture/discussion on sequencing of DNA and work with *Drosophila* DNA sequences (Olson 2004)	Individualization and matching of evidence to suspects in a more specific way than RFLP	Extension to phylogenetics and evolution	Quiz on DNA and replication; Reading questions; Phylogenetic analysis of *Drosophila* sequences (construction of cladogram)
Electrophoresis	Separation of DNA fragments (RFLP products) using agarose gel and electrical charge (Forensic DNA Fingerprinting Kit, *www.explorer.bio-rad.com*)	Visualization of individual differences between people's DNA (DNA fingerprint)	Separation of particles and negative charge of DNA	Self and peer assessment of results; Figure of results included with formal report of simulated crime scene

FIGURE 5

Student-constructed lists of equipment, techniques, and materials seen on the second *CSI* episode ("Bloodlines") shown in class.

Note that the "novel equipment" consists mostly of items students are familiar with in everyday life.

Equipment and techniques on *CSI* that students considered similar to classroom / field experience	Novel equipment and techniques (not used in class or seen in the field trips)	Materials collected by investigators at the *CSI* crime scenes
Pipette, Gloves, Tweezers, Centrifuge, Black light, Tubes, Lab coats, Oven, Thermal cycler, Vortex, Computer, DNA samples, Microscope	Camera, Forensic artistry, Cotton swabs, Fingerprints, Shoe prints, Microsatellites (instead of RFLP)	Blood Sperm Hair Fibers

the difficulty of pipetting DNA into a gel, and they were amazed by the obvious skill of an experienced lab scientist.

Forensics as an umbrella project strategy

We were able to successfully combine the scientific interest generated by popular television with students' inherent curiosity about mysteries and to channel this interest into effective biology lessons. The concepts and skills we chose to cast in the context of our forensic unit could easily have fit into other biology units throughout the year, although such alternate placement may have made them less interesting to students.

The forensic umbrella allowed us to effectively engage students in topics we planned to cover anyway. Even the safety and hygiene aspects of the labs were more interesting because students could see beyond their usual, vague acknowledgement that they might hurt themselves; it seemed very important that they avoid contaminating the evidence in order to find the true criminal, match the parents to their real children, or locate the stolen bird.

We hope that this information will be useful to other teachers interested in forensics but unable to devote an entire course to the topic. The forensics umbrella is not limited to biology; other aspects of forensics such as fingerprints, questioned documents, fire-debris analysis, and blood-splatter and tool-mark evidence are more applicable to chemistry and physics-based courses. Based on the data we collected, we are confident that most lessons taught in the forensic context will be well received by students. ■

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