

Investigating How Students Learn Using Collaborative Activities With A Forensic  
Science Focus In A General Education Physical Science Class

by  
Brooke Taylor Morgan

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Brooke Taylor Morgan

APPROVED:

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Dr. Judith Iriarte-Gross  
Department of Chemistry

---

Dr. George Murphy  
Director, Department of Forensic Science

---

Dr. Meredith Dye  
Department of Sociology and Anthropology  
Honors Council Representative

---

Dr. Robert D. Sieg  
Department of Biology  
UHC Administrative Representative

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## *Abstract*

This thesis project has a combination of research and creative aspects. In this thesis project, emphasis was placed on the development of an interdisciplinary introductory forensic science lab manual, in addition to examining a hands-on pedagogical approach. This project, which is targeted specifically to non-science majors, enhances students' interest in science as well as their fundamental understanding of the subject. I placed importance on actively involving the students in the learning process through the employment of new activity-based curriculum based on the fundamental concepts of forensic science and incorporate those into the physical science classroom. Emphasis was made on building connections between the science that students learn in the classroom and the world in which they live.

**List of Figures:**

Figure 1: Ethics Concepts.....	28
Figure 2: The Next Bones Concepts.....	29
Figure 3: Hit and Run Concepts.....	29
Figure 4: Loops, Whorls, and Arches Concepts.....	30
Figure 5: Drug Tests Concepts.....	30
Figure 6: Who Are You Concepts.....	31
Figure 7: Real World Application Comparison.....	31
Figure 8: Pre-SALG Survey Levels.....	32
Figure 9: Student Highs from Pre-SALG Survey.....	33
Figure 10: Post-SALG Gains Survey.....	33

## Table of Contents:

Acknowledgments.....	iii
Abstract.....	iv
List of Figures.....	v
Introduction.....	1
Thesis Statement.....	5
Methodology.....	5
Results.....	10
Limitations.....	15
Discussion.....	15
References.....	17
Appendix.....	19
A-1: IRB Approval Letter.....	19
A-2: Pre-SALG Survey.....	20
A-3: Post-SALG Survey.....	24
A-4: Figures.....	28
A-5: Lab Manual.....	34

## **Introduction:**

Positive attitudes towards science, in addition to science literacy, are prominent issues in today's society. How can one communicate science to the public without losing the elements of scholarship that constitute the essence of true understanding? In the words of Charles Simonyi: "The goal of public understanding of science is for the people to appreciate the order and beauty of the abstract and natural worlds which is there, hidden, layer-upon-layer. To share the excitement and awe that scientists feel when confronting the greatest of riddles. To have empathy for the scientists who are humbled by the grandeur of it all" [6].

A common goal of general education science nationwide is to guide non-science majors towards scientific literacy so they can make informed decisions about issues related to science and technology. The General Education Program at Middle Tennessee State University has a vision to provide all students with the intellectual building blocks that will make it possible to find meaning in an ever-changing world [2].

The General Education courses that fulfill the Natural Science Requirement at MTSU will foster in students the ability to:

1. "Conduct an experiment, collect and analyze data, and interpret results in a laboratory setting.
2. Analyze, evaluate, and test a scientific hypothesis.
3. Use basic scientific language and processes, and be able to distinguish between scientific and non-scientific explanations.
4. Identify unifying principles and repeatable patterns in nature, the values of natural diversity, and apply them to problems or issues of a scientific nature.

5. Analyze and discuss the impact of scientific discovery on human thought and behavior" [3].

Introductory general education science courses for non-majors often serve as the students first and only encounter with the discipline. Unfortunately, the students' interest in scientific studies can be hindered by the structure of the classroom in general education classes. More inquiry and problem-solving need to be introduced in science classrooms as a type of reformation.

There are many "best practices" for science curriculum reform that emerge in the literature. Tomizuka and Tobias in *Breaking the Science Barrier: How to Explore and Understand the Sciences*, explained how to succeed in college math and science classes. Success is an ambiguous word when it comes to students' performance in the classroom for it is ever changing and evolving. Success does not fit into a mold nor can it be computed with a mathematical equation. Tomizuka and Tobias explored the fundamentals of understanding science and the kinds of study skills and thinking needed by successful college students. The meanings of terms in science, how understanding and learning change from high school to college, and making connections among facts are also covered [9]. Shelia Tobias pointed out in *They're Not Dumb, They're Different: Stalking the Second Tier*, that non-science majors who have a basic knowledge of science, mathematics, and technology and who have completed a lab science have a "competitive edge" in the world today [8]. Feinstein, Allen, and Jenkins suggest that in order to become competent individuals (one who has suitable or sufficient skill, knowledge, experience in that particular field), students need to learn to access and



interpret science in the context of complex, real-world problems, be able to judge the credibility of scientific claims, and cultivate deep and durable involvement in science [1].

In the past, traditional cookbook labs that follow “prescribed” directions, also known as expository labs, have been the leading teaching style used in the classroom. However, cookbook labs do not engage non-majors and thus is part of the rote instruction problem. Using cookbook labs limits the students’ access to exploration. Most general education science courses use these expository labs. Expository labs are labs that use scripted procedures and directions that are given to students in order to minimize potential equipment damage and injury, while maximizing potential for generating usable data [4]. Expository labs are “teacher-centered”, in that; the laboratory activities are carried out in a scripted, predetermined fashion under direct supervision of the instructor. Tobias argues that the teacher-centered approach is the most widely adopted method used in college science classrooms and labs [9]. With such methods implemented, students are not provided the opportunities to explore the limitations of an experiment or theory they are trying to validate. In such restricted environments, non-science major students are not allowed to “deviate from the prescribed procedures as to minimize time wasted, injury, equipment damaged, and material wasted. Nor do they provide opportunities for students to create their own understanding of the phenomena they are investigating” [4]. Rather, the expository environment utilizes repetitious procedures that doesn’t allow the students to connect the steps to the bigger goal of the experiment. Cookbook labs fail to stimulate thinking by students, instead only enforce a step-by-step thinking mentality.

In contrast, hands-on and practical lab activities allow students to take an active role in their learning of physical science, and in this research, by means of forensic

science. Research shows that student-centered, hands-on labs and activities create the perfect learning environment where the student will actually absorb the material. Students have difficulty constructing meaning from cookbook labs, but inquiry-based labs require ongoing intellectual engagement from the students.

In this research project, "Investigating how students learn using collaborative activities with a forensic science focus in a general education physical science class," I investigated how interest and excitement about physical science could be generated through the use of collaborative learning coupled with an interdisciplinary approach of forensic science to learning basic scientific concepts. This project focused on fostering science literacy rather than forcing students to learn a broad range of science content that will be forgotten once the class has ended. The purpose of this research project was to develop and evaluate a new activity-based curriculum centered on the fundamental concepts of forensic science. Emphasis was made on making and understanding the connection between what the non-science students learn in the classroom and the world in which they live through the use of forensic science. An additional objective of this project was to include a concentration on how science is actually conducted since a majority of non-science majors do not have an accurate understanding of what scientists do on a daily basis. Lab activities were focused around the use of transferrable skills. This class was targeted specifically to non-science Honor's majors to elicit and enhance student's interest in science as citizens. The principle goal of this study was to see if collaborative learning activities help students succeed in general education physical science courses.

**Thesis Statement:**

The goal of this research was to evaluate how engaging and hands-on activities support learning of forensic science. Traditional/expository labs were not used in this research. I hypothesized that through collaborative learning and activities, non-science students would have a positive attitude towards science and a growth in science literacy. Another aspect of this thesis was the improved understanding of general education physical science as well as further interest and inquiries about science. Overall, students would leave the class with a greater awareness of the role that science plays in everyday life.

**Methodology:**

This research project consisted of three main parts: developing, teaching, and assessing. I began this project by developing an array of lab activities related to forensic science. I then taught each forensic science lab in the fall semester of 2014 in an Honors Physical Science class. The final component of this project was the assessment of the SALG surveys given throughout the course of the semester.

This project's impact on student learning was assessed in several ways. Traditional modes of evaluation such as quizzes, group or team work in the classroom, lab reports, and project grades were incorporated, in addition an on-line survey. The SENCER, Science Education for New Civic Engagement and Responsibilities, Student Assessment of Learning Gains (SALG) allowed students to rate how specific activities in SENCER courses help aid their learning success [5]. The SALG assessment tool also

asked students to report on their science skills and interests, as well as the civic activities in which they engage [7]. SENCER's philosophy includes:

"(1) get more students interested and engaged in learning in science, technology, engineering and mathematics (STEM) courses

(2) help students connect STEM learning to their other studies

(3) strengthen students' understanding of science and their capacity for responsible work and citizenship" [5].

The participants consisted of 18 students enrolled in the Fall 2014 Honors PSCI 1130/1131, with one student dropping the class halfway through the semester. Twelve females and five males were involved in the final analysis. Any students under the age of 18 were excluded from this study. To determine if pedagogical approach is the defining factor in the success of the students, quantitative as well as quantitative comparison analyses were conducted in the Honors PSCI 1130/1131 class.

I received IRB certification during the Spring 2014 semester. Throughout the course of the Fall 2014 semester, I taught various labs and administered SALG surveys after each lab activity as well as a pre and post-SALG survey for the class. The SALG surveys reflected the concepts of the lab activity performed during the class time. The pre and post-SALG surveys focused and compared the attitudes and learning gains at the beginning of the semester to the end of the semester.

The curriculum consisted of various labs and activities based on the techniques and skills utilized by forensic scientists. Forensic Science and Criminal Justice disciplines encompass a wide range of subject matters. In order for the students to fully grasp the interdisciplinary field of forensics, I utilized activities and labs from each major

subsection of the field. Labs and activities ranged from fingerprint development, examination of questioned documents, to DNA extraction. Ethical principles were also incorporated into the activities with real life scenarios to illustrate the importance of proper procedure and conduct. I also considered the “CSI effect” on the students’ connection with forensic science and demonstrated the difference between their perceptions taken from television with actual reality. Technology and state of the art equipment was employed into the class activities and labs with the Vernier LabQuest. The LabQuests were useful for engaging the students in the experiments and allowed for a greater hands-on experience [10].

The pedagogical approach that I used was an open-ended instruction approach. This involved lessons that are less structured and students are encouraged to provide more complex/multiple answers. Instead of expository labs, the activities incorporated student-designed investigations that could lead to various “right” answers. Students were encouraged to explore different avenues and not instructed in one particular direction. I also incorporated differentiated learning into the various lab activities to account for the various learning styles.

Below are the layouts and descriptions of the lab activities that I taught during the semester. I paid special attention to connect each lab with the common theme present within each topic. In addition to the description, quotes from students are added to emphasize their learning gains from the activity.

**Ethics:** This activity was an introduction to the challenges that scientists face when making decisions that don’t necessarily have a black or white answer. The students had to

discuss what decision they would make and why. For example, the students had to decide if and when to tell a supervisor when they witnessed a wrongful lab practice.

*“I never realized how important it was for ethics to be the central focus on science.”*

**The Next Bones:** This lab activity focused on the relationship of measurement and prediction. The main objectives for this lab included determining the relationships that most accurately parallels the body proportions in estimating height. The students also applied the Canons of Proportions to forensics by estimating another student’s height from a limited number of body part measurements.

*“I better understand the importance of accurate measurements in the field of forensics because in these cases, one small error in a measurement can translate to an even larger error in other measurements.”*

**Hit and Run:** This lab activity focused on the relationship between acceleration and velocity. The main objective of this lab was to simulate the use of an event recorder (EDR) in order to show how the evidence gathered can be used for legal purposes. The students also recreated accident scenes via an analysis of the data gathered from the Vernier LabQuest.

*“I was able to see how measurements can be the deciding factor in either proving or disproving suspect's stories when it comes to forensic investigations.”*

**Loops, Whorls, and Arches:** This lab activity focused on the relationship of identification of patterns and prediction. The main objective for this lab was to define the

three basic properties that allow individual identification by fingerprints. The students also obtained an inked, readable fingerprint from each finger and classified each print based on recognition of the general ridge patterns.

*“I better understand the importance of accurate measurements in this field because inaccurate measurements can skew an analysis or wrongfully send someone to prison.”*

**Drug Tests:** This lab activity focused on the concepts of qualitative and quantitative observations. The main objective of this lab activity was to identify an unknown powder using physical and chemical properties. By the end of this activity, the students were able to distinguish between physical and chemical properties as well as qualitative and quantitative observations.

*“I better understand the importance of accurate measurements because I observed that inaccurate readings can come from having too little or too much of a substance.”*

**Who Are You:** This lab activity explored the concepts of DNA extraction and the physical components of the structure. By the end of this lab activity, the students were able to extract DNA from different types of fruit as well as identify and observe DNA with the naked eye. The DNA extraction lab, Who Are You, encountered complications and produced little to no results. So we took advantage of the activity that went “wrong”, and we de-emphasized the idea of the “right” answer and allowed the students to wrestle with ambiguity.

*“I’m not really interested in science, but this type of science [forensic science/DNA lab] would be my favorite.”*

**The Ink is Still Wet:** Although this lab was offered for extra credit purposes only, to replace a missed lab, the students that conducted the experiment seemed to enjoy the lab. This activity involved exploring the concepts of light and color. The main objective for this lab activity was to identify an unknown ink sample by its light absorbance characteristics.

*“It was neat to see how inks react differently in different liquids and the different color compositions.”*

### **Results:**

After the data collection, I selected questions from the surveys that related to student learning. I focused on questions that reflected the understanding and learning success from each lab activity. I selected specific concepts that each lab activity focused on and analyzed the results from the SALG survey conducted after each specific lab activity in addition to the post-SALG survey. I ran unpaired t-tests on each lab concept.

The Ethics lab examined the relationship between “good and correct” science. Since this was an introductory lab, I didn’t offer a survey after the activity. The data gathered is from the pre-SALG survey and post-SALG survey. The post-SALG survey showed that the majority of students greatly gained understanding in this relationship. (Figure 1). The pre-SALG survey average score was  $3.6 \pm 0.3$ , compared to  $5.1 \pm 0.4$ , in the post-SALG survey. Significant difference was found between the two samples when the t-test was ran (two-tailed t-test,  $n = 15$ ,  $p = 0.0044$ ).

From the SALG survey conducted after The Next Bones lab activity, I selected and analyzed the question: *Presently I understand the relationships between those main*



*concepts of measurement and prediction from this activity.* As for the post-SALG survey the corresponding question was analyzed: *As a result of your work in this class, what GAINS did you make in your understanding of the relationships between those main concepts of measurement and prediction.* I compared the results from the two with the students' average SALG score (Figure 2). Student views on this question did not statistically differ between the lab ( $4.0 \pm 0.3$ ) and the post-SALG ( $4.1 \pm 0.4$ ) surveys (two-tailed t-test,  $n = 7-15$ ,  $p = 0.91$ ).

From the SALG survey conducted after Hit and Run lab activity, I selected and analyzed the question: *Presently I understand the relationships between those main concepts of acceleration and velocity from this activity.* As for the post-SALG survey the corresponding question was analyzed: *As a result of your work in this class, what GAINS did you make in your understanding of the relationships between those main concepts of acceleration and velocity.* I compared the results from the two with the students' average SALG score (Figure 3). The students reported moderate knowledge at an average of  $3.2 \pm 0.2$  on the lab survey compared to  $3.9 \pm 0.4$ , on the post-SALG survey. No significant difference was found between the two samples (two-tailed t-test,  $n = 10-16$ ,  $p = 0.17$ ).

From the SALG survey conducted after Loops, Whorls, and Arches lab activity, I selected and analyzed the question: *Presently I understand the relationships between those main concepts of identification and prediction from this activity.* As for the Post-SALG survey the corresponding question was analyzed: *As a result of your work in this class, what GAINS did you make in your understanding of the relationships between those main concepts of identification and prediction.* I compared the results from the two

with the students' average SALG score (Figure 4). Students views on this question did not statistically differ between the lab ( $3.5 \pm 0.2$ ) and the post-SALG ( $3.9 \pm 0.3$ ) surveys (two-tailed t-test,  $n = 13-16$ ,  $p = 0.28$ ).

The lab activities, Drug Tests and Who Are You, focused on the understanding of quantitative and qualitative observations. From the SALG survey conducted after Drug Tests and Who Are You lab activities, I selected and analyzed the question: *Presently I understand the relationships between those main concepts of qualitative and quantitative observations from this activity*. As for the Post-SALG survey the corresponding question was analyzed: *As a result of your work in this class, what GAINS did you make in your understanding of the relationships between those main concepts of qualitative and quantitative observations*. I compared the results from the two with the students' average SALG score (Figure 5 and 6). The average scores after each lab activity were  $3.6 \pm 0.3$  and  $4.1 \pm 0.2$ , respectively. As for the post-SALG survey scores,  $4.0 \pm 0.4$  was the average score for both. No significant difference was found following the t-test (two-tailed t-test,  $n = 14-15$ ,  $p = 0.45$ ; two-tailed t-test,  $n = 13-15$ ,  $p = 0.87$ ).

Real world applications were also incorporated into each lab activity. One particular question was kept consistent throughout the course of the surveys. This question offered better insight to the students' understanding with a higher replication number. The survey assessed the understanding of how studying this subject (lab activity concept) helps people address real world issues. I analyzed the results from the SALG surveys conducted after each lab activity and compared it to the scores from the pre-SALG survey responses. The average SALG score on the pre-SALG survey was 3.1.

From each lab, we can see an increase of the average SALG score; however, the numbers were consistent across each specific labs (Figure 7).

I also analyzed comments about how the students' perspective and understanding on forensic science had changed as result of this class. Two major themes were present in the comments I evaluated. The comments pointed towards the students' gains in understanding what a forensic scientist does in addition to better understanding of the scientific process. I listed several comments related to the two prominent themes below:

What does a (forensic) scientist do?:

- *“Forensic science is fascinating and requires time and patience.”*
- *“I learned that forensic scientists do a much larger range of things than what I thought they did.”*
- *“I learned how important and relevant forensic science is to our society and how often questions of ethics are raised in the field.”*
- *“...[the labs] put into perspective how much forensic science actually covers.”*

Scientific process:

- *“I learned that forensic scientists must look at every piece of evidence before drawing conclusions. Evidence is not always as it appears to be. This was exceptionally true in the lab where we compared different powdered substances to identify an unknown substance; while outwardly, one substance seemed to be the unknown substance, it wasn't until I has compared all the data (pH, reactivity, conductivity, etc.) that I was able to draw a conclusion.”*

- *“I learned the details behind the scientific processes shown on television and the realities of forensic science and the necessity for forensic scientists.”*
- *“Through the lab activities I learned the importance of accurate measurements and how to better work with a group of people to reach a common goal.”*
- *“The forensic lab activities taught me that first you have to always report the data you got and not alter it. [The labs] also taught me to work in groups with others to find out the solution for the problems in the lab activity.”*
- *“I learned that you must be ethical in science. I also learned that science is a process and if you make a wrong step, the entire experiment can go wrong.”*
- *“In the forensic science lab activities, I learned that proper documentation is always necessary.”*

Last but not least, to examine the larger scope of the project, I selected the four main sections of Understanding, Skills, Attitudes, and Integration to analyze and compare the pre-SALG survey results and post-SALG survey results (Figures 8-10). In Figure 8, the students’ initial understanding, present skills, current attitudes, and habits of integration were examined. Figure 9 assessed the students’ beginning levels of understanding, skills, attitudes, and integration. Figure 10 depicts the overall increases the students gained in understanding, skills, attitudes, and integration. Attitudes and integration showed the most gains.

The overall breakdown of the stats show that if the students initially scored little/less on the pre-SALG survey, they subsequently scored lower on gains. The students

that entered the class with a good/great deal on the pre-SALG survey showed a continued increase in their gains. Students that started with a good/great showed moderate to little gains from the course. I made an assumption that since this was an Honors course, the students entered the class with prior understanding, skills, attitudes, and integration.

### **Limitations:**

Some of the challenges that I faced while conducting this experiment was the low replication number. Since the results was limited to the number of students enrolled in the PSCI 1130/1131 class, my data analysis options were very restricted. I also encountered a problem with very few students completing the SALG survey after each lab activity at the beginning of the course. In order to combat this problem, I used an incentivized approach to receive more responses. I also had to account for the fact that the class was Honors; therefore, the students entered the course with prior knowledge, skills, and understanding of the science.

### **Discussion:**

This project's pedagogical approach, which was targeted specifically to non-science majors, enhanced the students' interests in science as well as their fundamental understanding of the subject. I placed emphasis on actively involving the students in the learning process through the employment of new activity-based curriculum focused on the fundamental concepts of forensic science and incorporated those into the physical science classroom. I stayed away from the typical cookbook labs and introduced a more

hands-on and interactive approach. Pyatt and Sims discovered that in order for the students to reach maximum potential, a less expository approach must be taken [4]. Emphasis was placed on making and understanding the connection between the science that students learn in the classroom and the world in which they live. As Tobias pointed out, non-science majors that have a basic understanding of science and its applications are better prepared for the work force [8].

From the results, one can conclude that the students gained understanding about how science is relative to society as well as a better understanding of the scientific process and the procedures involved. The students also gained a sense of integrating critical thinking skills into everyday situations.

The results also support that the pedagogical approach used in this research accomplished the main goals of SENCER's philosophy. Students were more interested and engaged in learning after leaving the classroom. The students also made connections from their learning to other fields and everyday applications. Students left the class with a strong understanding of science and their capacity for responsible work and citizenship.

Although this project faced limitations, based on the results, I support my hypothesis that through collaborative learning and activities, non-science students will have a positive attitude towards science and a growth in science literacy. I conclude that the engaging and hands-on activities supported the learning of forensic science. Overall, the students left the class with a greater awareness of the role that science plays in everyday life.

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## Appendices:

### A-1: IRB Approval Letter



2/14/2014

Investigator(s): Brooke T. Morgan, Judith M. Iriarte-Gross, Ph.D  
Department: Chemistry  
Investigator(s) Email Address: btm3m@mtmail.mtsu.edu, Judith.Iriarte-Gross@mtsu.edu

Protocol Title: Who Dun It: Investigating How Students Learn Using Collaborative Activities in General Physical Science via Forensic Science

Protocol Number: #14-214

Dear Investigator(s),

Your study has been designated to be exempt. The exemption is pursuant to 45 CFR 46.101(b)(1) Evaluation/Comparison of Instructional Strategies/ Curricula.

We will contact you annually on the status of your project. If it is completed, we will close it out of our system. You do not need to complete a progress report and you will not need to complete a final report. It is important to note that your study is approved for the life of the project and does not have an expiration date.

The following changes must be reported to the Office of Compliance before they are initiated:

- Adding new subject population
- Adding a new investigator
- Adding new procedures (e.g., new survey; new questions to your survey)
- A change in funding source
- Any change that makes the study no longer eligible for exemption.

The following changes do not need to be reported to the Office of Compliance:

- Editorial or administrative revisions to the consent or other study documents
- Increasing or decreasing the number of subjects from your proposed population

If you encounter any serious unanticipated problems to participants, or if you have any questions as you conduct your research, please do not hesitate to contact us.

Sincerely,

Lauren K. Qualls, Graduate Assistant  
Office of Compliance  
615-494-8918

## A-2: Pre-SALG Survey:

### Understanding

1. Presently, I understand...	not applicable	not at all	just a little	somewhat	a lot	a great deal
1.1 How scientific research is carried out	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
1.2 Scientific processes behind important scientific issues in the media	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
1.3 The use of science in determining public policy	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
1.4 Science is important to decisions I make	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

### Skills

2. Presently, I can...	not applicable	not at all	just a little	somewhat	a lot	a great deal
2.1 Think critically about scientific findings I read about in the media	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2.2 Determine what is -- and is not -- valid scientific evidence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2.3 Make an argument using scientific evidence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2.4 Determine the difference between science and pseudo-science	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2.5 Understand tables and graphs	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2.6 Understand mathematical and statistical formulas commonly found in scientific texts	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2.7 Find scientific journal articles using library/Internet databases	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2.8 Extract main points from a scientific article and develop a coherent summary	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2.9 Give a presentation about a science topic to your class	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2.10 Pose questions that can be addressed by collecting and evaluating scientific evidence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2.11 Organize a systematic search for relevant data to answer a question	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2.12 Write reports using scientific data as evidence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2.13 Find articles relevant to a particular problem in professional journals or elsewhere	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2.14 Critically read articles about issues raised in class	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2.15 Identify patterns in data	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2.16 Recognize a sound argument and appropriate use of evidence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2.17 Develop a logical argument	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2.18 Write documents in discipline-appropriate style and format	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2.19 Work effectively with others	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2.20 Prepare and give oral presentations	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2.21 What do you expect to be able to do at the end of the course that you cannot do now?						

### Attitudes

3. Presently, I am...	not applicable	not at all	just a little	somewhat	a lot	a great deal
3.1 Interested in discussing science with friends or family	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3.2 Interested in reading about science and its relation to civic issues	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3.3 Interested in reading articles about science in newspapers, journals or on the Internet	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3.4 Interested in taking additional science courses after this one	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3.5 Interested in majoring in a science-related field	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3.6 Interested in exploring career opportunities in science	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3.7 Interested in teaching science	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3.8 Enthusiastic about the subject	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3.9 Interested in discussing the subject area with friends or family	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3.10 Interested in taking or planning to take additional classes in this subject	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3.11 Confident that I understand the subject	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3.12 Confident that I can do this subject	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3.13 Comfortable working with complex ideas	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3.14 Willing to seek help from others (teacher, peers, TA) when working on academic problems	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3.15 Please comment on your present level of interest in this subject.	<div style="border: 1px solid black; height: 40px; width: 100%;"></div>					

### Integration of learning

4. Presently, I am in the habit of...	not applicable	not at all	just a little	somewhat	a lot	a great deal
4.1 Discussing science-related issues informally	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4.2 Discussing civic or political issues informally	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4.3 Reading science-related magazines not required by class	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4.4 Writing letters or emails to public officials about civic or political issues	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4.5 Writing letters or emails to public officials about science-related issues	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4.6 Talking with public officials about civic or science-related issues	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4.7 Debating or offering public comment on scientific issues	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4.8 Debating or offering public comment on civic or political issues	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4.9 Attending a meeting, rally, or protest about civic or political issues	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4.10 Writing a letter to the editor about civic or political issues	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4.11 Writing a letter to the editor about science-related issues	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

4.12 Connecting key ideas I learn in my classes with other knowledge	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4.13 Applying what I learn in classes to other situations	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4.14 Using systematic reasoning in my approach to problems	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4.15 Using a critical approach to analyzing data and arguments in my daily life	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4.16 Please comment on how you expect this material to integrate with your studies, career, and/or life?	<div></div>					

### Reasons for taking the course

5. Please tell us why you are taking this course.	strongly disagree	disagree	neutral	agree	strongly agree	not applicable
5.1 It is required and I am interested in the topic of the course	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5.2 It is required but I am not interested in the topic of the course	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5.3 It is not required but I am interested in the topic of the course	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5.4 The course fits my schedule	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5.5 It is a prerequisite for another course	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5.6 I heard good things about the teacher	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5.7 I was drawn to a science course that promised to address civic issues	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5.8 I was drawn to a course that promised to apply science to real world issues	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5.9 I did not know that the course addressed civic topics	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5.10 Did you take this course primarily for the activities related to forensic science?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

### Age

6. What is your age group?	18 or younger	19-21	22-30	31-40	41-49	Over 50
6.1 My age group is...	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

### Major

7. What best characterizes your status as having selected an interdisciplinary major in college?	Science major	Not a science major	Undecided	Plan to major in science	Plan to major in another area
7.1 my concentration status is	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

### Class rank

8. What level are you at in college?	Freshman	Sophomore	Junior	Senior	Post-graduate	Not a degree-seeking student
8.1 My class rank is...	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

### Teacher Preparation

9. .	Yes	No	Undecided
9.1 Are you in a teacher preparation program?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

### GPA

10. What is your current GPA in a system that assumes a 4.00 as an A (highest score possible)?	4.00-3.60	3.01-3.59	2.51-3.00	2.01-2.50	2.00 or lower
10.1 My GPA is...	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

### Number of science classes

11. How many college-level science courses have you enrolled in so far -- including this one?	One	Two or three	Four to five	Six to seven	More than eight
11.1 I am taking and have taken this many college-level science classes...	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

### A-3: Post-SALG Survey:

#### Your understanding of class content

1. As a result of your work in this class, what GAINS DID YOU MAKE in your UNDERSTANDING of each of the following?	no gains	a little gain	moderate gain	good gain	great gain	not applicable
1.1 The main concepts explored in this class	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
1.2 The relationships between the main concepts	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
1.3 The following concepts that have been explored in this class	no gains	a little gain	moderate gain	good gain	great gain	not applicable
1.3.1 The relationship between "good and correct" science and ethics	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
1.3.2 The relationships between those main concepts of measurement and prediction	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
1.3.3 The relationships between those main concepts of acceleration and velocity	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
1.3.4 The relationships between those main concepts of identification and prediction	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
1.3.5 The relationships between those main concepts of qualitative and quantitative observations	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
1.4 How Ideas from this class relate to Ideas encountered in other classes within this subject area	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
1.5 Please comment on HOW YOUR UNDERSTANDING OF FORENSIC SCIENCE HAS CHANGED as a result of this class.	<div style="border: 1px solid black; height: 40px; width: 100%;"></div>					

#### Increases in your skills

2. As a result of your work in this class, what GAINS DID YOU MAKE in the following SKILLS?	no gains	a little gain	moderate gain	good gain	great gain	not applicable
2.1 Finding articles relevant to a particular problem in professional journals or elsewhere	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2.2 Critically reading articles about issues raised in class	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2.3 Identifying patterns in data	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2.4 Recognizing a sound argument and appropriate use of evidence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2.5 Developing a logical argument	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2.6 Writing documents in discipline-appropriate style and format	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2.7 Please comment on what SKILLS you have gained as a result of this class.	<div style="border: 1px solid black; height: 40px; width: 100%;"></div>					

### Class impact on your attitudes

3. As a result of your work in this class, what GAINS DID YOU MAKE in the following?	no gains	a little gain	moderate gain	good gain	great gain	not applicable
3.1 Enthusiasm for the subject	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3.2 Interest in taking or planning to take additional classes in this subject	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3.3 Confidence that you understand the material	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3.4 Your comfort level in working with complex ideas	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3.5 Your willingness to seek help from others (teacher, peers, TA) when working on academic problems	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3.6 Please comment on how has this class CHANGED YOUR ATTITUDES toward this subject.						

### Integration of your learning

4. As a result of your work in this class, what GAINS DID YOU MAKE in INTEGRATING the following?	no gains	a little gain	moderate gain	good gain	great gain	not applicable
4.1 Connecting key class ideas with other knowledge	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4.2 Applying what I learned in this class in other situations	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4.3 Using systematic reasoning in my approach to problems	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4.4 Using a critical approach to information and arguments I encounter in daily life	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4.5 What will you CARRY WITH YOU into other classes or other aspects of your life?						

### The Class Overall

5. HOW MUCH did the following aspects of the class HELP YOUR LEARNING?	no help	a little help	moderate help	much help	great help	not applicable
5.1 The instructional approach taken in this class	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5.2 The pace of the class	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5.3 Non-forensics related labs	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5.4 Group (team) problem solving as a tool to aid learning	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5.5 Please comment on how the INSTRUCTIONAL APPROACH to this class helped your learning.						

### Class Activities

6. HOW MUCH did each of the following aspects of the class HELP YOUR LEARNING?	no help	a little help	moderate help	much help	great help	not applicable
6.1 Attending lectures	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6.2 Participating in discussions during class	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6.3 Invited guest speakers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6.4 Field trip speakers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6.5 Specific Class Activities	no help	a little help	moderate help	much help	great help	not applicable
6.5.1 Ethics	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6.5.2 The Next Bones	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6.5.3 Drug Testing	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6.5.4 Hit and Run	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6.5.5 Loops, Arches, Whorls	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6.5.6 Who Are You	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6.6 Please comment on how the CLASS ACTIVITIES helped your learning.	<div></div>					

### Assignments, graded activities and tests

7. HOW MUCH did each of the following aspects of the class HELP YOUR LEARNING?	no help	a little help	moderate help	much help	great help	not applicable
7.1 Graded assignments (overall) in this class	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
7.2 The number and spacing of lab activities	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

### Class Resources

8. HOW MUCH did each of the following aspects of the class HELP YOUR LEARNING?	no help	a little help	moderate help	much help	great help	not applicable
8.1 Online notes or presentations posted by Instructor	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

### The information you were given

9. HOW MUCH did each of the following aspects of the class HELP YOUR LEARNING?	no help	a little help	moderate help	much help	great help	not applicable
9.1 Explanation given by instructor of how to learn or study the materials	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>



### Support for you as an individual learner

10. HOW MUCH did each of the following aspects of the class HELP YOUR LEARNING?	no help	a little help	moderate help	much help	great help	not applicable
10.1 Interacting with the instructor during class	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
10.2 Working with teaching assistants outside of class (e.g., recitation, office hours)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
10.3 Working with peers outside of class (e.g., study groups)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
10.4 Please comment on how the SUPPORT YOU RECEIVED FROM OTHERS helped your learning in this class.	<div></div>					

### Age

11. What is your age group?	18 or younger	19-21	22-30	Over 30
11.1 My age group is...	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

### Major

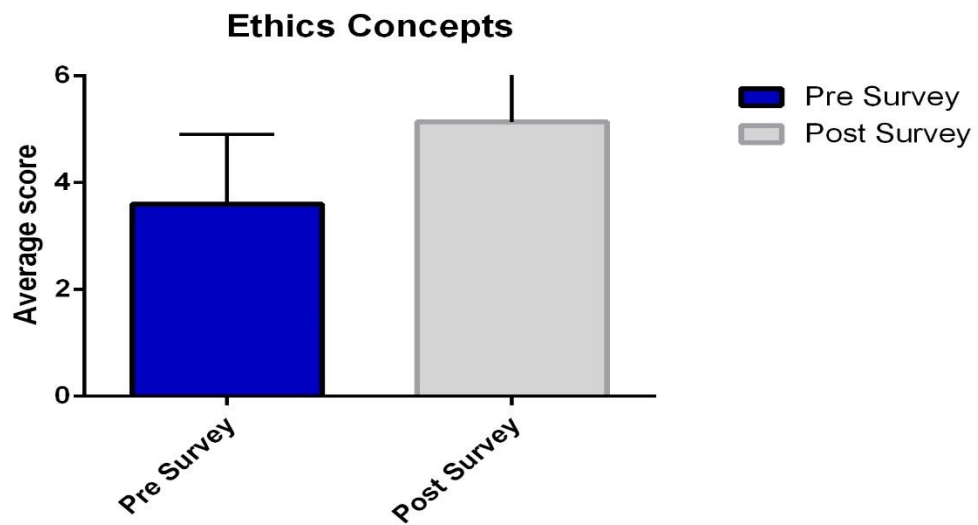
12. What best characterizes your status as having selected an interdisciplinary major in college?	Science major	Non-science major	Undecided	Plan to major in science	Plan to major in another area
12.1 my concentration status is...	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

### Class Rank

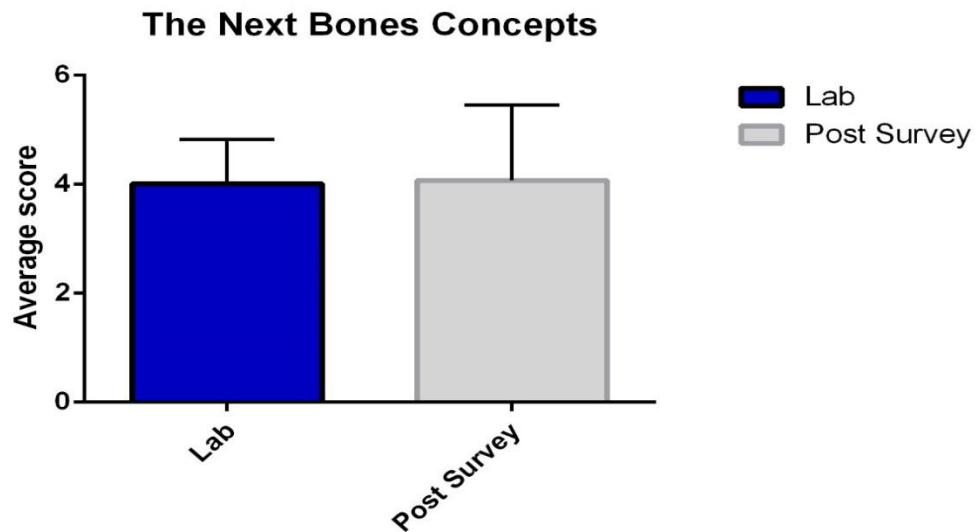
13. What level are you at in college?	Freshman	Sophomore	Junior	Senior	Post-graduate	Not a degree-seeking student
13.1 My class rank is...	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

**Figures:**

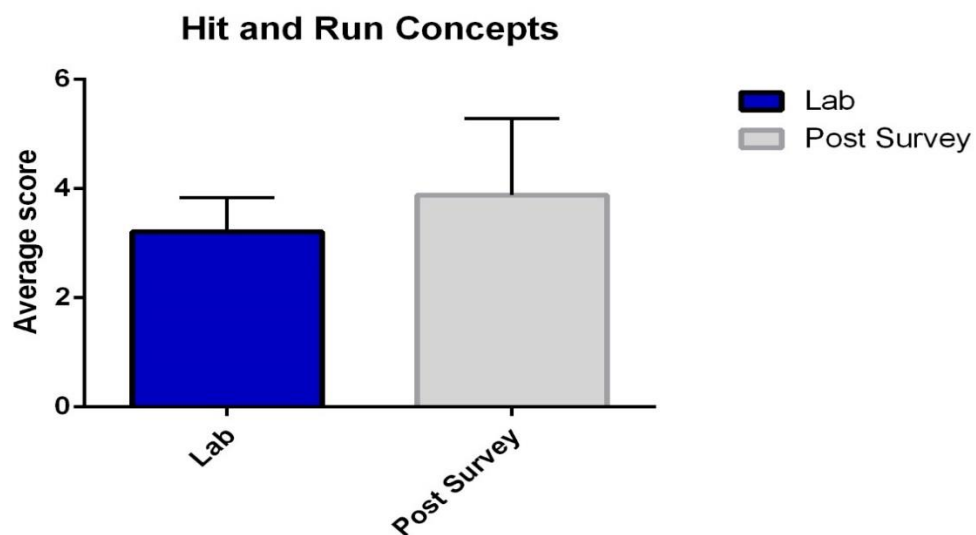
**Figure 1:** The comparison between students' average score from the pre-SALG survey and post-SALG survey on understanding the relationship between “good and correct” science.



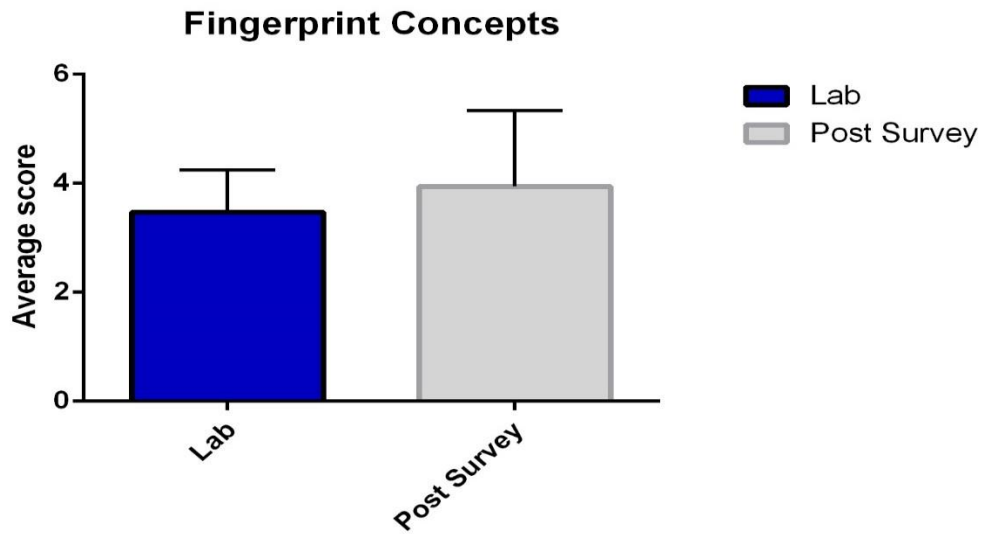
**Figure 2:** Students' average score after The Next Bones lab activity compared to post-SALG survey on understanding the relationship between measurement and prediction.



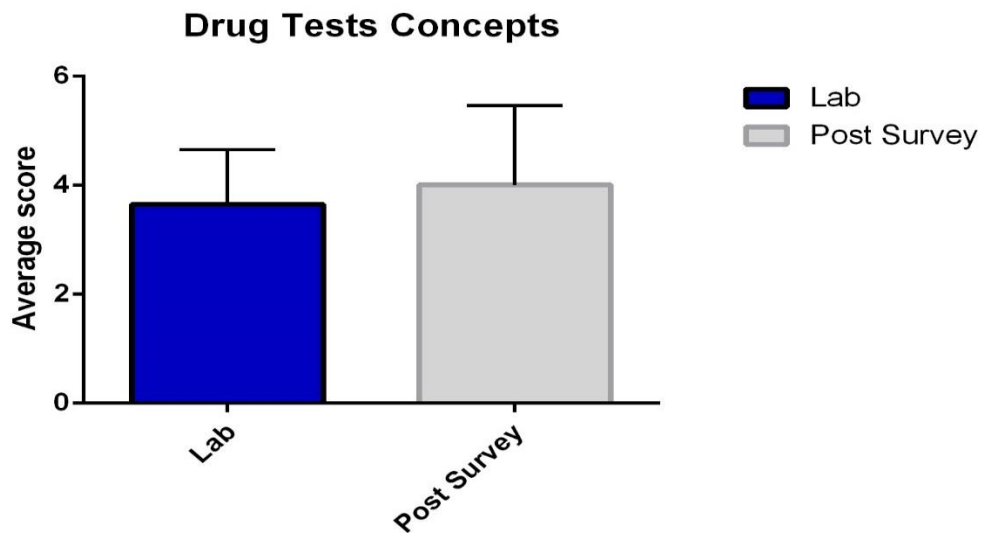
**Figure 3:** Students' average score after Hit and Run lab activity compared to post-SALG survey on understanding the relationship between velocity and acceleration.



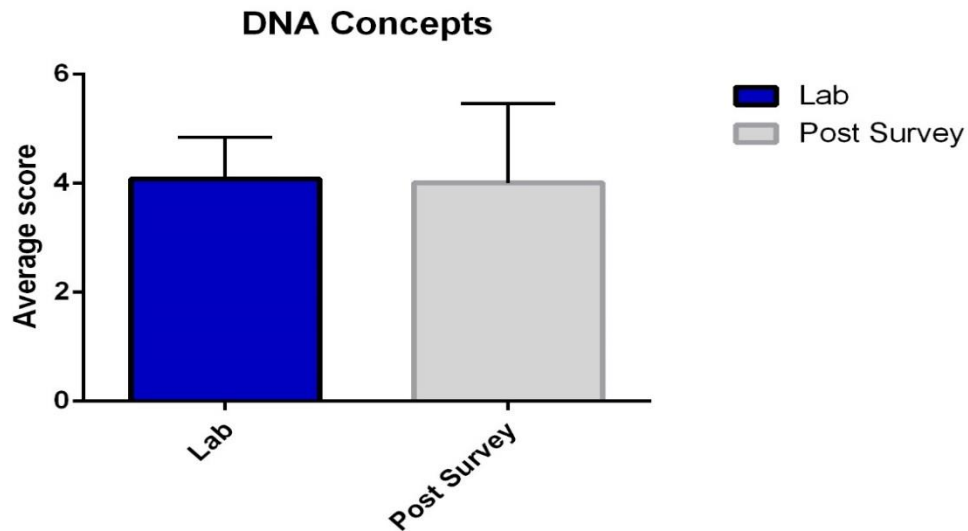
**Figure 4:** Students' average score after Loops, Whorls, and Arches lab activity compared to post-SALG survey on understanding the relationship between patterns and identification.



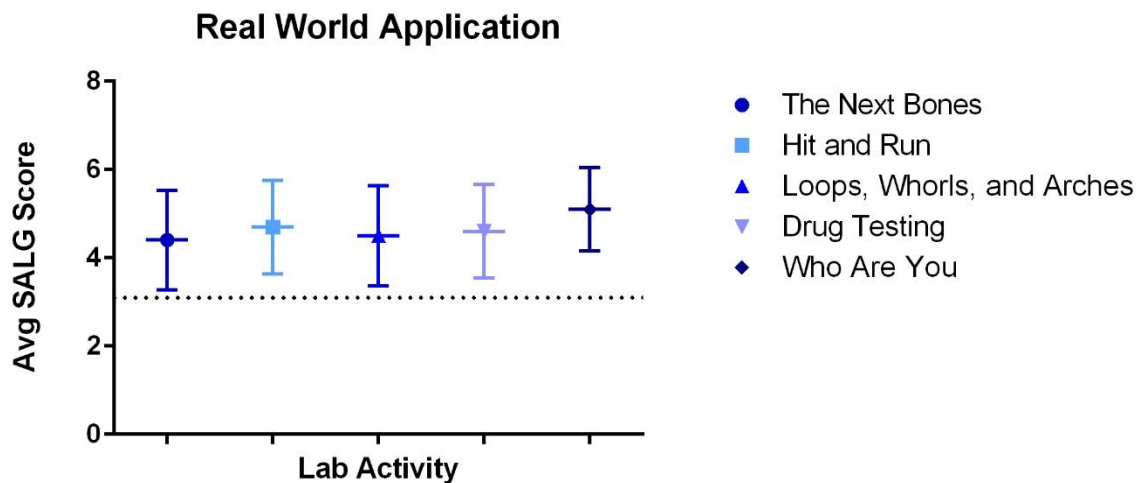
**Figure 5:** Students' average score after Drug Tests lab activity compared to post-SALG survey on understanding the relationship between qualitative and quantitative properties.



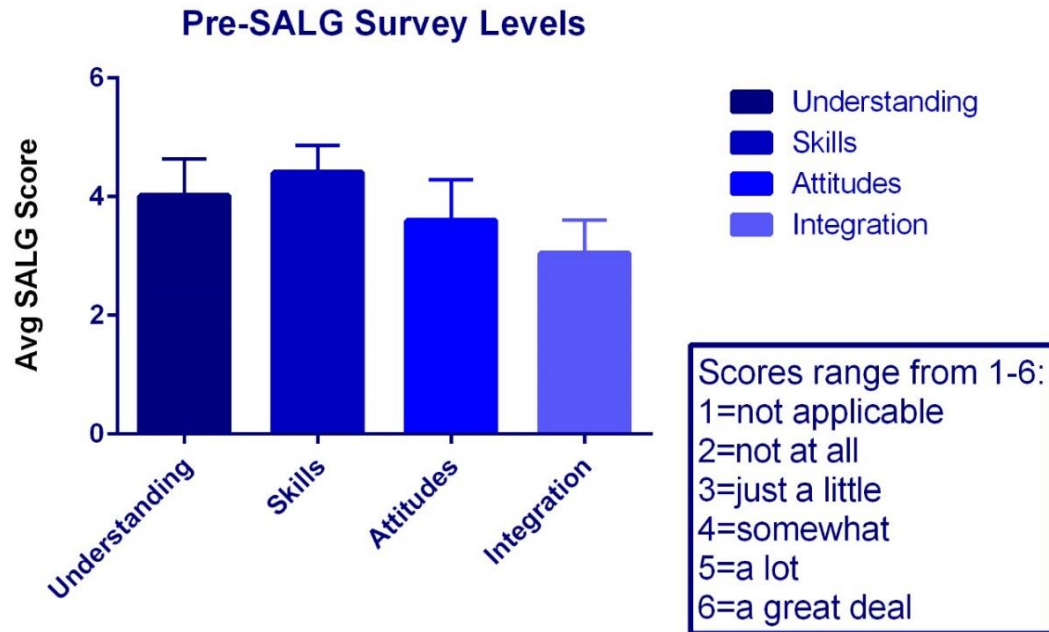
**Figure 6:** Students' average score after Who Are You lab activity compared to post-SALG survey on understanding the relationship between qualitative and quantitative properties.



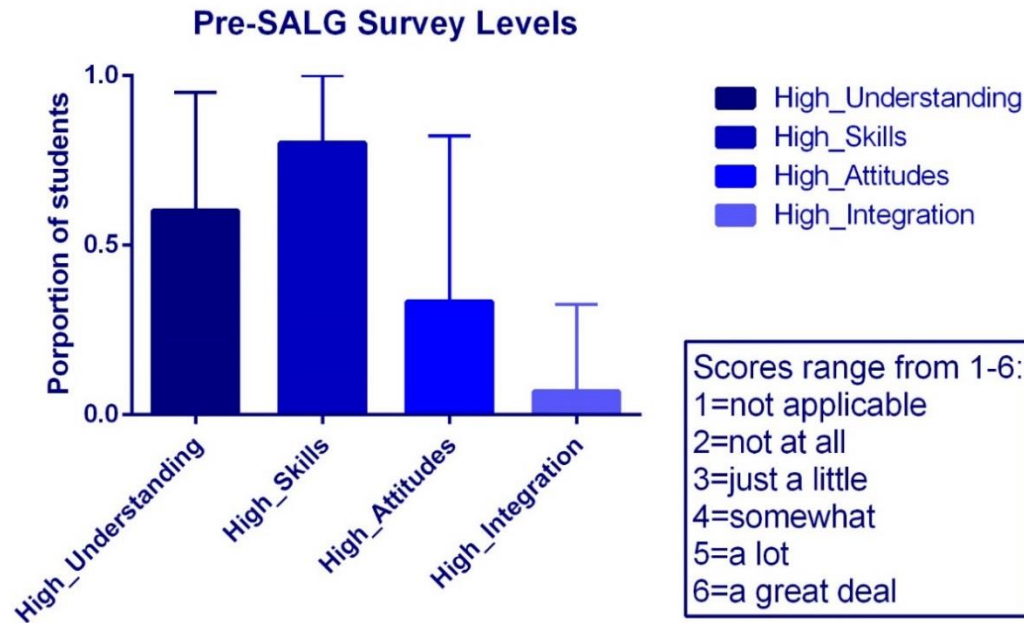
**Figure 7:** Comparison of students' average SALG score from each lab activity on how studying this subject helps people address real world issues. The dotted line represents the average SALG score from the pre-SALG survey.



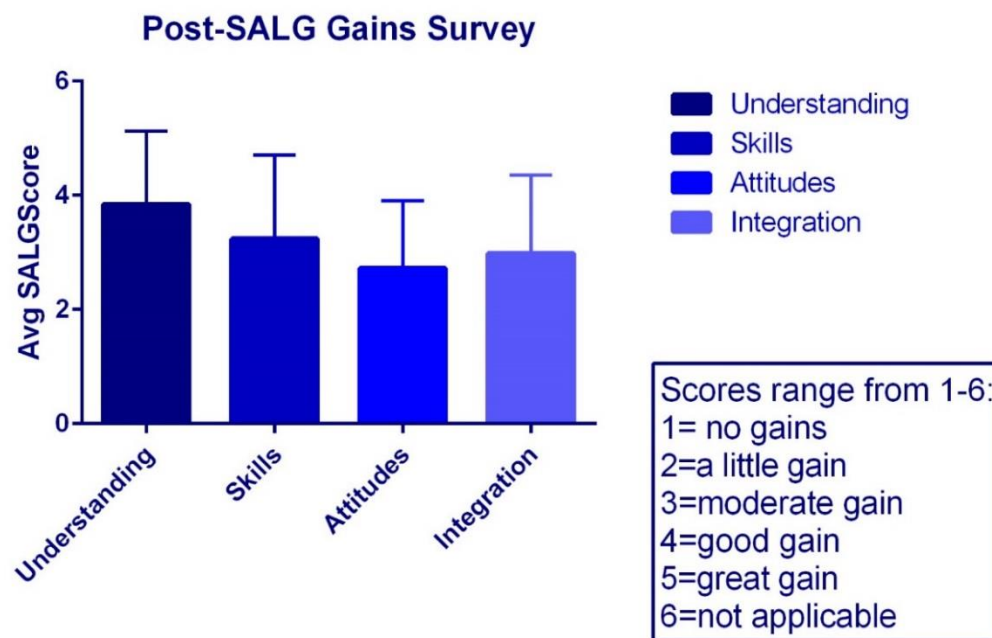
**Figure 8:** Average SALG scores from pre-SALG Survey Levels of Understanding, Skills, Attitudes, and Integration.



**Figure 9:** Proportion of students that entered the class with a lot or great deal of Understanding, Skills, Attitudes, and Integration.



**Figure 10:** Average SALG scores from post-SALG survey depicting student gains.





# The Interdisciplinary World of Forensic Science

By

Brooke Taylor Morgan  
PSCI 1130/1131  
Honors Thesis Project



# Ethics in Forensic Science

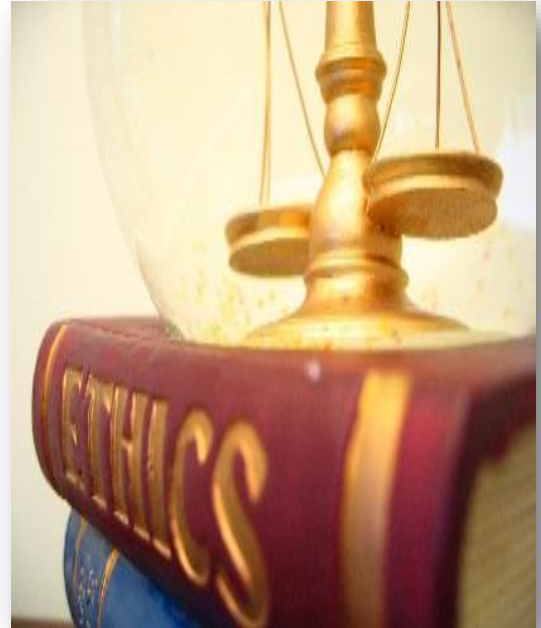
## Background

Forensic science—the application of science to civil and criminal law—is a field that is grounded in applied ethics. The identification, collection, and preservation of any piece of forensic evidence will ultimately involve numerous individuals. At any step within the process, evidence can be deliberately or accidentally mishandled.

## Objectives

*By the end of this activity, you will be able to:*

- Understand the basic components of ethics
- Compare legal, ethical, and moral standards
- Recognize ethical issues and standards



## Procedure

1. In groups, read simulated situations below carefully.
2. Decide with of the three options would be the most ethical with detailed explanation.
3. Group discussion on the gray areas of ethics.

### Three Simulated Situations:

1. **You arrive at a crime scene and find out it is the house of your wife's ex-husband and you have a long history of conflict in the past five years. Is it ethical for you to continue on the case?**
  - a. "No, I would excuse myself from the case mainly to avoid appearance of impropriety."
  - b. "Yes, as long as I can explain my conflict of interest to my supervisor and let him decide."
  - c. "Yes, as long as I can separate the personal issue and not let it affect my judgment."

**2. The defense attorney made a mistake in defending the case on a DNA data result and would lose the case for sure. Do you have an obligation to correct him?**

- a. "No, each side will use findings in the manner in which they see fit. I can't change that, such is the nature of the beast."
- b. "Yes, if the statement is misleading or in error, as a scientist I must try to rectify the situation because a scientist can't knowingly let misleading or erroneous testimony stand."
- c. "Yes, I will inform my supervisor of it and let him decide."

**3. If you know your partner has falsified some data on a test you did together, would you report it to your supervisor?**

- a. "Yes, otherwise I could be involved in the consequences."
- b. "No, I was not the one that made the mistake."
- c. "Depends on the nature of the consequences and/or misconduct."

# The Next Bones: Height and Body Proportions

## Background

Leonard da Vinci drew the “Canons of Proportions” around 1492 and provided a text to describe what the ideal proportions of a perfect man should be. The drawing was based on the earlier writings of Vitruvius, a Roman architect. Some of the relationships described include:

- A man’s height is 24 times the width of his palm.
- The length of the hand is one-tenth of a man’s height.
- The distance from the elbow to the armpit is one-eighth of a man’s height.
- The maximum width at the shoulders is one-half of a man’s height.
- The distance from the top of the head to the bottom of the chin is one-eighth of a man’s height.
- The length of a man’s outstretched arms is equal to his height.



## Objectives

*By the end of this activity, you will be able to:*

- Determine which of these relationships most accurately parallels your body proportions in estimating height.
- Describe how to apply the Canons of Proportions to forensics by estimating someone’s height from a limited number of different body parts.

## **Materials**

Metric ruler

Pen and paper

Calculator

Excel Spreadsheet

## **Part 1:**

### **Procedure**

1. Standing flat on the floor with your back to a wall, have your partner carefully measure your height to the nearest tenth of a centimeter. Keep the top of your head level (parallel to the floor).
2. Record your results on Data Table 1.
3. Have your partner measure to the nearest 0.1cm and record each of the following measurements of your body:
  - a. Width of your palm at the widest point
  - b. Length of the hand from first wrist crease nearest your hand to the tip of the longest finger
  - c. Distance from elbow to highest point in the armpit
  - d. Maximum width of shoulders
  - e. The distance from the top of the head to the bottom of the chin
  - f. The length of outstretched arms
4. Repeat steps 1-3, taking the body measurements of your partner and record in Data Table 2.
5. Your partner records your data in his or her Data Table 2.
6. Calculate and record your and your partner's estimated height using the proportions given on the data tables.
7. Determine and record the difference between your actual height and your calculated height in data tables 1 and 2. Use + and – symbols.

### Data Table 1: Your Body Relationships

All measurements recorded in centimeters

Gender of person measured \_\_\_\_\_

A	B	C	D	E
Trait	Actual Size (cm)	Multiply by	Calculated Total (cm)	Difference b/t actual and calculated height (cm)
<i>Height</i>		X 1 =		
<i>Palm width</i>		X 24 =		
<i>Hand length</i>		X 10 =		
<i>Distance from armpit to elbow</i>		X 8 =		
<i>Width of shoulders</i>		X 4 =		
<i>Head to chin length</i>		X 8 =		
<i>Outstretched arms</i>		X 1 =		

### Data Table 2: Your Partner's Body Relationships

All measurements recorded in centimeters

Gender of person measured \_\_\_\_\_

A	B	C	D	E
Trait	Actual Size (cm)	Multiply by	Calculated Total (cm)	Difference b/t actual and calculated height (cm)
<i>Height</i>		X 1 =		
<i>Palm width</i>		X 24 =		
<i>Hand length</i>		X 10 =		
<i>Distance from armpit to</i>		X 8 =		

## *The Next Bones*

<i>elbow</i>				
<i>Width of shoulders</i>		X 4 =		
<i>Head to chin length</i>		X 8 =		
<i>Outstretched arms</i>		X 1 =		

### **Case Analysis**

1. Which measurement and relationship most accurately reflected your height?
2. Which measurement and relationship most accurately reflected your partner's height?
3. Which measurement was the least accurate in estimating your height?
4. Explain why using the Canons of Proportions on teenagers to estimate height would provide less accurate data than using the Canons of Proportions on adults.
5. Describe a crime scene that could use the Canon of Proportions to help estimate the height of a person.

### **Part 2:**

#### **Procedure**

1. The distance from our elbow to armpit is roughly the length of your humerus. Record the humerus length and actual length from everyone in your class and complete Data Table 3.
2. Create a graph in Excel. Graph the length of the humerus on the x-axis vs. height on the y-axis. Be sure to include on your graph the following:
  - i. Appropriate title for graph
  - ii. Set up an appropriate scale on each axis

- iii. Label units (cm) on each of the x and y axes
- iv. Plot the data and create the best-fit line

**Data Table 3: Comparison of Humerus to Actual Height**

Name	Length of Humerus (cm)	Actual Height (cm)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		

### **Case Analysis**

1. Suppose a humerus bone was discovered at a construction site. From the graph, explain how you could estimate the person's height from the length of the humerus.
2. List the variables that would need to be considered when trying to estimate someone's height from a single bone.



# Hit and Run

## Background

Event data recorders, or automobile black boxes, can make many contributions to automobile safety; however, they also raise many important questions concerning an individual's right to privacy. The balance of these two seemingly conflicting objectives is one of the dilemmas of life in the technological age.

The relationship between the two graphs (distance vs. time and velocity vs. time) that the Motion Detector generates is important for students to understand. They should learn the fundamentals of how the behavior of one graph can predict the appearance of the other graph. For example, when the velocity is positive and increasing, the vehicle is moving away from the Motion Detector.



## Objectives

*By the end of this activity, you will be able to:*

- Simulate the use of an event data recorder (EDR) in order to show how the evidence gathered by this device can be used for legal purposes.
- Show how accident scenes can be recreated through an analysis of the data that are gathered by an EDR.
- Learn how distance traveled, velocity, and acceleration are related to one another.
- Learn how the appearance of an acceleration, velocity, or distance vs. time graph can be used to predict the appearance of the other graphs.

## Materials

LabQuest

Vernier Motion Detector

Rolly chair or other free rolling object

## Procedure

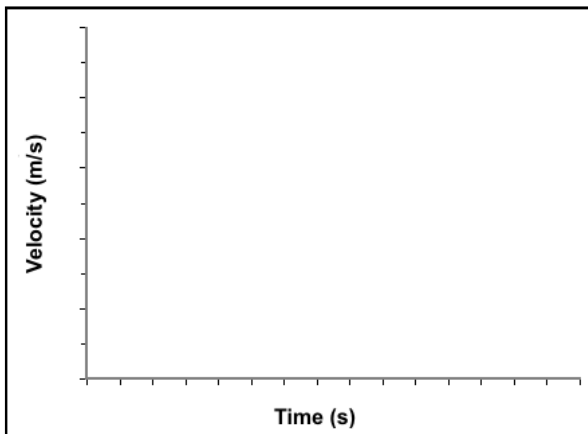
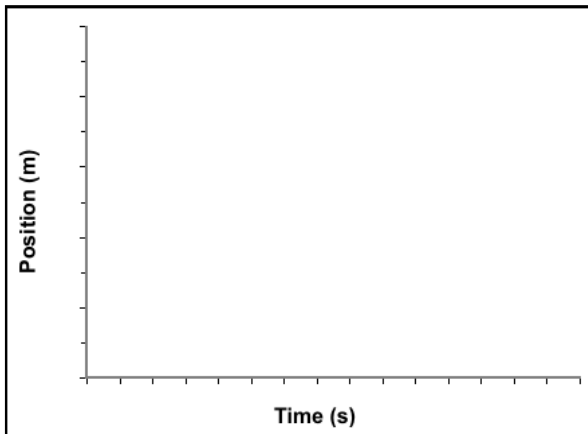
4. Prepare the Motion Detector for data collection.
5. Open the pivoting head. If the Motion Detector has a sensitivity switch, set it to **Track**.

## ***Hit and Run***

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6. Connect the Motion Detector to DIG 1 of LabQuest.
7. On the Meter screen, tap Distance. Change the data-collection length to 3 seconds. Select OK.
8. Place the Motion Detector on the lab table. The Motion Detector should be facing the chair, and they should be about 30 cm apart. Remove any surrounding objects so that the data you acquire will be relatively “noise” free.
9. Perform a test run with your chair. Have one team member push the chair and release it. Have another team member check the readings on the screen. You do not need to record the motion at this point. Just be sure that the Motion Detector is measuring the increasing distance as the chair moves away. Also be sure that the chair is pushed gently enough that it stops before the end of the table.
10. Position the team members so that one can start data collection and the other can push the chair **AWAY** from the Motion Detector.
11. Start data collection and push the chair away after data collection begins. Be sure to push the chair away in the same manner that you did in your test run.
12. Examine the distance and velocity graphs. These graphs should be relatively smooth, indicating that you picked up the motion of the chair and not other objects. If the graphs of the distance and velocity are not relatively smooth (an absolutely smooth graph is rarely observed), repeat data collection.
13. Sketch these graphs in the Evidence Record. Then complete the Case Analysis.

**Evidence Record**



**Case Analysis**

1. Look at the velocity vs. time graph. At what time did the chair begin to move?
2. What was the maximum velocity of the chair?
3. At what time did the chair reach its maximum velocity?
4. How far did the car move before it reached its maximum velocity?

## ***Hit and Run***

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5. EDRs in vehicles record information on velocity and acceleration for moving vehicles. The data recorded by EDRs help reconstruct the events of an accident. For example, data from the EDR can show when a car's brakes were applied, if at all.

Suppose a vehicle were traveling at a constant speed, using cruise control, when suddenly the brakes were applied until the vehicle stopped. Sketch a velocity vs. time graph for this situation. Label the point at which the brakes were applied and the point at which the vehicle came to a complete stop.

6. Do the EDR data taken from the suspects support their stories (Case File 12)? Do the EDR graphs suggest that any of these suspects is the culprit in the hit and run? Explain your answers.

## Hit and Run

**CHALLENGE:** Recreate the graphs below using real life scenarios while “driving” your chair. At the end of the activity period, demonstrate your understanding of Hit and Run to the class.



### Case File 12

#### Hit and Run:

Using information from an event data recorder to reconstruct an accident

Replicate data from an event data recorder to identify the culprit in a hit and run.

#### Police Report

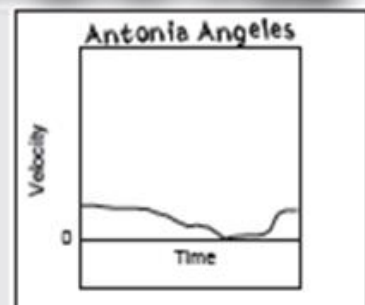
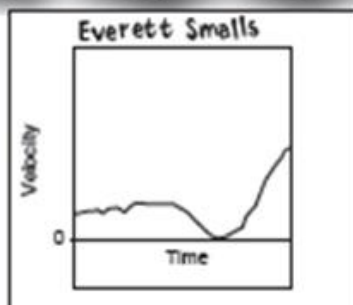
Rania Sallum, 58, was struck by a large, dark-colored SUV Wednesday around 7:20 a.m. Sallum could not see the driver or read the license plate, but she knows that she was struck by the front right bumper of the vehicle, which then slowed almost to a stop before speeding off. She estimates that the incident occurred between 7:15 and 7:25 a.m. A hit-and-run bulletin and vehicle description went out to all officers. Three police teams spotted vehicles with front right bumper damage and recorded the following information from their drivers:

Natalya Ludnova, 25--pulled over for speeding when the officer noticed bumper damage--claimed that damage was due to hitting the curb while parking.

Everett Smalls, 38--brought in for blocking a fire lane--claimed that bumper was damaged in a stop-and-go rush hour fender bender.

Antonia Angeles, 53--pulled over for speeding when the officer noticed bumper damage--claimed a neighbor backed into her car as she drove past his driveway.

EDR data downloaded from each car for the 10 seconds before and after the bumper collision show that each occurred between 7 and 8 a.m. Wednesday. See below.



# Loops, Whorls, and Arches

## Background

Fingerprints have been used for identification throughout history, but it was Sir William Herschel in Jungipoor, India, who first recognized their true potential. He was the first to espouse the theory that all fingerprints are unique to an individual and are permanent throughout a person's lifetime. These principles were later scientifically investigated and promulgated by Sir Francis Galton, a British anthropologist. A student of his, Juan Vucetich, made the first criminal fingerprint identification in 1892 when he used Francis Rojas' bloody fingerprint to convince a jury she had murdered her two sons. Today, we now accept as common fact that 1) all fingerprints are unique, and no two are exactly identical, 2) a fingerprint will remain unchanged during a person's lifetime, and 3) fingerprints have distinct patterns that can be classified and used for comparison. Fingerprints can be divided into three main types: loops, whorls, and arches. There are subcategories for each of these. Loops are subdivided into radial loops (the loop enters and exits the finger on the side closest to the thumb) and ulnar loops (the loop enters and exits the finger on the side closest to the pinky finger). Arches can be plain (the ridges are flat or only show a slight peak) or tented (sharp, well defined peak). Whorls can be plain, central pocket (elevated, usually smaller whorl pattern), double loop (whorl made of two distinct loop patterns), or accidental (combination of all of the above).



In order to conclusively match individual fingerprints, fingerprint examiners use ridge characteristics, also known as minutia. The most common types of ridge characteristics are bifurcations, ridge endings, and islands, though there are several different categories and subcategories for each of these. A single rolled fingerprint may have more than 100 different ridge characteristics. In the United States there is no minimum number of ridge characteristics that must be used to match up two fingerprints (though eight more is considered "standard" and twelve is "sufficient").

## Objectives

*By the end of this activity, you will be able to:*

- Define the three basic properties that allow individual identification by fingerprints.
- Obtain an inked, readable fingerprint for each finger.

## *Loops, Whorls, and Arches*

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- Recognize the general ridge patterns (loops, whorls, and arches).
- Identify and classify ridge characteristics.

### **Materials**

Fingerprint Record Sheet

Ink Pad

White Balloons

### **Part 1:**

#### **PROCEDURE**

1. Roll the “pad” portion of your thumb over the ink pad from the left side of your thumb to the right. You do not have to push down really hard!
2. Roll the “pad” portion of your thumb from the left side of your thumb to the right in the correct box on your paper to make a thumbprint.
3. Continue this process to make a fingerprint of all ten fingers on the Fingerprint Record worksheet.
4. Use your notes to help you figure out what type of pattern is found in each of your fingerprints. Label each one with the pattern’s name.

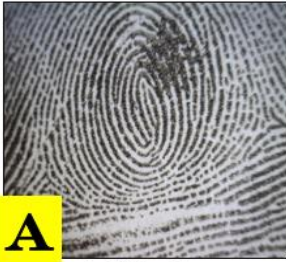
### **Part 2:**

#### **PROCEDURE**

1. Partially inflate a balloon. Do not tie it off.
2. Open fingerprinting pad and gently roll one fingertip.
3. Apply finger to balloon surface near the center (where the balloon will expand the most), being careful not to smudge or twist while lifting the finger from the balloon surface.
4. Circle and name 4 different minutiae on each print (see page 5 for examples).

## Case Analysis

1. Classify the following prints:



**A**

Left Hand

---



**B**

Right Hand

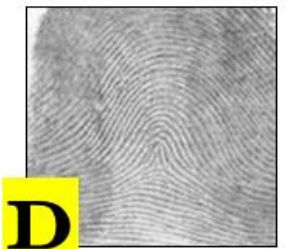
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**C**

Right Hand

---



**D**

Right Hand

---



## ***Loops, Whorls, and Arches***

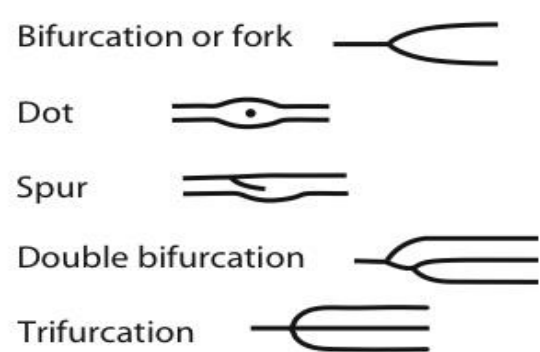
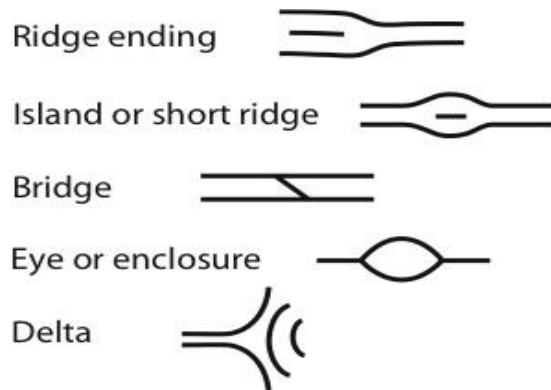
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Left Hand

- 
2. What fingerprint patterns do your fingerprints have?
  3. Focus on a single fingerprint. Detail some of the minutiae in that fingerprint.
  4. Compare your left thumb print to that of your lab partner. What patterns are similar? What patterns are different?
  5. Why is the examination and identification of fingerprints important in the field of criminal justice and forensic science?
  6. What did you learn about the process of science by conducting this activity?

## Sample Ridge Characteristics for Identification



# Drug Tests

## Background

Forensic labs are often called in to identify unknown powders, liquids and pills that may be illicit drugs. There are basically two categories of forensic tests used to analyze drugs and other unknown substances: **Presumptive tests** (such as color tests) give only an indication of which type of substance is present -- but they can't specifically identify the substance. **Confirmatory tests** (such as gas chromatography/mass spectrometry) are more specific and can determine the precise identity of the substance.



## Objectives

*By the end of this activity, you will be able to:*

- Identify an unknown powder using physical and chemical properties.
- Distinguish between physical and chemical properties.
- Distinguish between qualitative and quantitative observation.

## Materials

LabQuest

Vernier pH Sensor

Vernier Conductivity Probe

Spoons or weighing paper

stirring rod

Six 50 mL beakers or cups

wash bottle (with distilled water)

magnifying glass

## Drug Tests

vinegar

5 known "drug" samples (5g of each)

1 unknown "drug" samples (5g)

Distilled water

balance

lint-free tissues

goggles (1 pair per student)

Filter paper



### Case File 7

#### *Drug Tests: Identifying an unknown chemical*

Use quantitative and qualitative analyses to identify the powder in Mr. Orlow's car.

#### **Police Report**

Patrol officers pulled over Mr. Yuri Orlow for reckless driving last night at 8:50 p.m. A preliminary Breathalyzer test showed that Mr. Orlow was intoxicated. Mr. Orlow consented to a search of the vehicle, in which the officers found traces of a white powder that seemed to have leaked across the leather of the passenger seat. The officers think that Mr. Orlow might have thrown a bag of the unknown substance out the open passenger-side window before pulling over. A search of the snowy road has revealed nothing. The powder has been sent to the lab for testing.

Mr. Orlow has been charged with driving recklessly and awaits a second charge pending the results of the tests on the white powder.

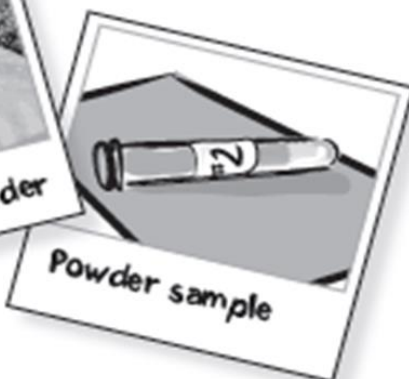
Enclosed are two photographs of Mr. Orlow's car and an evidence vial containing a sample of the powder.



Beer bottles



Unknown powder



Powder sample

## Procedure

**CAUTION:** Obtain and wear goggles during this experiment. Avoid inhaling the powders. Do not taste or smell any of the powders. If you get any powder or liquid on your skin, wash it with water immediately. Tell your teacher right away if any spills or accidents occur.

### Part I Collecting the Data

1. Label five 50 mL beakers with numbers 1 through 5. Label one beaker “Unknown” for the powder taken from Mr. Orlow’s car. Using the balance, measure 2 g of each sample and place it in the proper beaker. To avoid cross-contamination of the other samples, use a different weighing paper or spoon for each sample. Save the spoons or weighing papers for use in Part V.
2. Observe the samples through the magnifying glass, and record your observations in the Evidence Record.

### Part II Preparing the Solutions

3. Prepare powder-and-water mixtures of the six samples.
  - a) Add 20 mL distilled water to each beaker prepared in Step 1. Stir the mixtures thoroughly with the stirring rod. **Note:** After stirring one sample, rinse the stirring rod with distilled water and dry it with a lint-free tissue before using it to mix another sample.
  - b) Stir each mixture once every 3 minutes for 15 minutes. After the final stir, let the mixtures settle for about 5 minutes.
  - c) Write any observations that you can make about the water mixtures into the Evidence Record. Were the powders very soluble, or not soluble at all?

### Part III Testing the pH of the Samples

4. Connect the pH Sensor to LabQuest and choose New from the File menu. If you have an older sensor that does not auto-ID, manually set up the sensor. **Note:** For this experiment, your teacher already has the pH Sensor in a pH soaking solution in a beaker. Be careful not to tip over the beaker when you connect the sensor to the interface.
5. Use the pH Sensor to determine the pH of the solution in each sample beaker.
  - a) Rinse the tip of the pH Sensor with distilled water from the wash bottle and place it into the liquid in the beaker containing sample 1. Gently swirl the sensor in the solution. Be careful not to let the tip of the sensor touch any solid material at the bottom of the beaker.
  - b) When the pH reading stabilizes, record the pH value in the Evidence



## ***Drug Tests***

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Record.

- c) Repeat this process for each of the remaining samples.
6. When you are finished, rinse the pH Sensor with distilled water and return it to its storage container.

### **Part IV Testing the Conductivity of the Samples**

- 7. Set the switch on the probe to the 0–20,000  $\mu\text{S}/\text{cm}$  setting. Disconnect the pH Sensor from the interface and connect the Conductivity Probe. Choose New from the File menu. If you have an older sensor that does not auto-ID, manually set up the sensor.
- 8. Choose Zero from the Sensors menu to zero the Conductivity Probe.
- 9. Collect conductivity data for each sample.
  - a) Place the tip of the probe into the beaker containing sample 1. The hole near the tip of the probe should be completely covered by the liquid. Gently swirl the probe in the solution.
  - b) Once the conductivity reading has stabilized, record the value in your Evidence Record.
  - c) Rinse the Conductivity Probe thoroughly with distilled water from the wash bottle before collecting data for the next sample. Blot the outside of the probe end dry using a tissue. It is *not* necessary to dry the *inside* of the hole near the probe end.
  - d) Repeat this process for each of the remaining samples.
- 10. Empty the remaining liquid from the beakers as directed by your teacher. Rinse and dry the beakers.

### **Part V Reaction of the Samples with Vinegar**

- 11. In the next test, you will observe the reaction of each of the samples with vinegar, an acid.
  - a) Using the balance, measure 2 g of each sample and put it in the proper beaker. To avoid cross-contamination of the samples, use the measuring papers or spoons that you used in Step 1 or use a new paper or clean spoon for each sample.
  - b) Add 10 mL of vinegar to each sample. Determine whether or not a chemical reaction takes place. Record your observations in the Evidence Record.
- 12. When you have observed and recorded your observations of all of the samples mixed with vinegar, then empty, rinse, and dry the beakers as directed by your teacher.

## ***Drug Tests***

### **Evidence Record**

Sample	General Appearance	Observations of Water Mixture	pH	Conductivity ( $\mu\text{S}/\text{cm}$ )	Reaction with Vinegar
1					
2					
3					
4					
5					
Unknown					

### **Case Analysis**

1. Based on your observations, which known sample do you think was most similar to the unknown powder found in Mr. Orlow's car? Do you think the unknown was an exact match to that known sample? Explain your answer.
2. Explain the difference between physical and chemical properties. Give two examples of physical properties and one example of a chemical property that you measured in the lab.
3. Explain the difference between qualitative and quantitative observations. Give one example of a qualitative observation and one example of a quantitative observation that you made in the lab.
4. Identify two tests, other than those that you carried out in this investigation, which forensic scientists can use to identify a suspected drug



# Who Are You

## Introduction

DNA stands for deoxyribonucleic acid. DNA is mostly located in the nucleus of cells. Pretty much anything that is alive has DNA. DNA is a double helix shape and can replicate itself. Base pairs in the DNA attach to a sugar-phosphate backbone. The four chemical bases in DNA are adenine (A), thymine (T), guanine (G) and cytosine (C).

The bases always pair up the same way (A with T and C with G) to form a base pair. The order, or sequence, of the base pairs determines how the organism is built. In all people, more than 99 percent of the sequence will be the same.

Once the investigator has extracted the DNA, a process called gel electrophoresis is used to separate out repeating segments of base pairs, according to length. Markers are put into place to bind with segments of the bases. Bases that do not bind with a marker are rinsed out of the sample. The binders used are radioactive and photographic film darkens the marked segments.

You are left with a picture that looks like a bar code. DNA profiles are lined up to compare where the repeating segments are in the sequence.



## Background

In this lab, you will extract or “spool” DNA from strawberry cells. Ripe strawberries are producing pectinases and cellulases which are already breaking down the cell walls. Most interestingly, strawberries have enormous genomes; they are octoploid, which means they have eight of each type of chromosome. The detergent in the shampoo helps to dissolve the phospholipid bilayers of the cell membrane and organelles. The salt helps to keep the proteins in the extract layer so they aren’t

precipitated with the DNA. DNA is not soluble in ethanol. When molecules are insoluble, they are dispersed in the solution and are therefore not visible. When molecules are insoluble, they clump together and become visible. The colder the ethanol, the less soluble the DNA will be in it. This is why it is important for the ethanol to be kept in the freezer or in an ice bath.



## ***Who Are You***

---

### **Objectives**

*By the end of this activity, you will be able to:*

- Know how to extract DNA from strawberries.
- Observe what DNA looks like to the naked eye.
- Learn that DNA is found in every living and once living thing.
- Understand that DNA is found in all the food we eat.

### **Materials (per group)**

1 strawberry (fresh or frozen)

10 mL DNA extraction buffer (soapy, salty water)

Filtering apparatus

Ice cold ethanol

Clear test tube

Heavy duty Ziploc baggie

### **Procedure**

1. Place strawberry in Ziploc bag and squish with hands for approximately 2 minutes.
2. Add 10 mL of cold extraction buffer to the bag and mix for 1 minute.
3. Pour the strawberry mush through funnel lined with cheesecloth. Allow the fluid to collect in a test tube until approximately 1/8<sup>th</sup> of the way full.
4. Gently trickle the cold ethanol down the side of the test tube (SLOWLY) until it is half full. You should see two layers like oil and vinegar make. Do not shake the tube or mix the layers. A white precipitate should start to appear.
5. Observe DNA!

### **Fun Fact:**

Cheek cells are collected as you swish the Gatorade, or salt water, around in your mouth.

The detergent breaks open the fatty molecules that make up the membrane of the cells and

## ***Who Are You***

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helps to remove any proteins that may be associated with the DNA. The DNA is then released into the solution.

DNA cannot dissolve in the rubbing alcohol, so it precipitates out as white strands. Although the double helix structure is not visible to the naked eye, this is the same procedure that is used to analyze DNA in labs.

### **Optional Procedure: Extract Your Own DNA**

1. Pour a squirt of dishwashing liquid into a test tube with water (1 part dishwashing liquid to 3 parts water).
2. Take about 20 mL of Gatorade in your mouth and swish it around. Do not swallow!
3. Spit the Gatorade into a clean cup.
4. Pour the Gatorade into the test tube with the dishwashing liquid. Place your thumb over the top of the test tube gently rock back and forth for a couple minutes.
5. Add a teaspoon of the ice cold ethanol to the test tube. Let it sit for a few minutes.
6. You should see the DNA separate out. If desired, use the pipet to place the DNA in a vial.

### **Materials**

Clear Gatorade, or salt water (1 teaspoon of salt in a cup of water)

Dixie Cup Test tube

Dishwashing Liquid Pipet (optional)

Rubbing Alcohol Vial (optional)

## **Case Analysis**

1. Do you think human DNA will look the same as strawberry DNA? Explain.
2. What was the purpose of mashing up the strawberry?
3. What does the extraction buffer do? (Hint: Extraction buffer contains soap. What does soap do when you wash your hands?)
4. What happened when you added the filtrate to the alcohol?
5. What did the DNA look like?
6. Remember that genes are found on chromosomes, and genes control traits. Give at least two examples of traits that are expressed in the strawberry.
7. Why would forensic scientists want to extract DNA from cells?
8. Could the DNA extracted using this simple technique be sufficient in identifying or studying characteristics of individuals? Explain.
9. What did you learn about the process of DNA analysis and how it relates to forensic science through this activity?

# The Ink is Still Wet

## Background

Chromatography is a method for analyzing mixtures by separating them into the chemicals from which they are made. It can be used to separate mixtures like ink, blood, gasoline, and lipstick.



## Case File 5

*The Ink Is Still Wet: Using colorimetry to identify an unknown ink*

Identify the ink on the ransom note to narrow down the suspects.



## ***The Ink is Still Wet***

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In ink chromatography, you are separating the colored pigments that make up the color of the pen. Even though a pen will only write in one color, the ink is actually made from a mixture of different colored pigments.

### **Objectives**

*By the end of this activity, you will be able to:*

- Identify an unknown ink by its light absorbance characteristics.
- Measure a solution's absorbance of different colors (wavelengths) of light.

### **Part 1:**

#### **Materials**

LabQuest	4 dropper bottles, 10 mL samples of different diluted black inks
Vernier Colorimeter	1 dropper bottle, with 10 mL of diluted
6 cuvettes	unknown black ink
Distilled water	Lint-free tissues

#### **Procedure**

CAUTION: Obtain and wear goggles during this experiment. Be careful not to ingest any solution or spill any on your skin. Inform your teacher immediately in the event of an accident.

1. Prepare the blank, each of the four standards, and the unknown for analysis.
  - a) Rinse an empty cuvette twice with about 1 mL of distilled water.
  - b) Use the colored wax pencil to write a zero on the lid of the cuvette.
  - c) Fill the cuvette 3/4 full with distilled water. Seal the cuvette with the lid. Dry the outside of the cuvette with a tissue.
  - d) Repeat Steps 1a–1c, using the four standard solutions and the unknown, rather than distilled water, and labeling the lids of the cuvettes appropriately (1 through 4 for the standard solutions and 5 for the unknown).

Remember the following:

- All cuvettes should be clean and dry on the outside.
- Handle a cuvette only by the top edge or ribbed sides, not the transparent sides.
- All solutions should be free of bubbles.

2. Connect the Colorimeter to LabQuest and choose New from the File menu. If you have an older sensor that does not auto-ID, manually set up the sensor.

3. Set up the data-collection mode.
  - a) On the Meter screen, tap Mode. Change the mode to Events with Entry.
  - b) Enter the Name (Sample) and leave the Units field blank. Select OK.
4. Calibrate the Colorimeter.
  - a) Open the Colorimeter lid. Place the blank (cuvette 0, containing distilled water) in the cuvette slot of the Colorimeter. Make sure that one of the transparent faces of the cuvette is pointing toward the white reference mark. Close the lid of the Colorimeter.
  - b) Press the < or > button on the Colorimeter to select a wavelength of 635 nm (Red).
  - c) Press the CAL button until the red LED begins to flash. Then release the CAL button. When the LED stops flashing, the calibration is complete.
5. You are now ready to collect absorbance data at 635 nm for the solutions.
  - a) Start data collection.
  - b) Place cuvette 1 in the Colorimeter, with the cuvette clean, dry, and with a transparent face pointing toward the reference mark.
  - c) After closing the lid, wait for the absorbance value displayed on the monitor to stabilize, then tap Keep.
  - d) Enter the sample number (from the lid) and select OK.
  - e) Remove the cuvette from the Colorimeter.
  - f) Repeat Steps 5b–5e for the remaining samples in cuvettes 2 through 6.
6. Stop data collection when you have collected data for all the samples.
7. In your Evidence Record, write down the absorbance values displayed in the data table.
8. Measure the absorbance of each solution at the three other wavelengths (or colors) that the Colorimeter can measure.
  - a) Repeat Steps 4–7 for the 565 nm (green) wavelength setting on the Colorimeter.
  - b) Repeat Steps 4–7 for the 470 nm (blue) wavelength setting on the Colorimeter.
  - c) Repeat Steps 4–7 for the 430 nm (violet) wavelength setting on the Colorimeter.
9. Discard the solutions as directed by your teacher.

## ***The Ink is Still Wet***

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### **Evidence Record**

Sample	Type of Ink; Appearance in Alcohol	Absorbance at 635 nm	Absorbance at 565 nm	Absorbance at 470 nm	Absorbance at 430 nm
1					
2					
3					
4					
5	Unknown				

Unknown is most likely \_\_\_\_\_

### **Part 2:**

#### **Objectives**

- Separate colors into their components using paper chromatography

#### **Materials**

Isopropanol

Pencil

Chromatography Paper

Permanent Markers

Beakers

Distilled Water

## **Procedure**

1. Cut chromatography paper into two pieces so that they fit into the beakers without bending or falling.
2. Using a pencil, draw a line approximately one inch from the bottom going across the width of each section of paper.
3. Place approximately 50 ml of water into a beaker. The water level must not rise above the pencil line.
4. Choose four ink pens for the ethanol sample. Place a small sample of each color on each of the vertical lines.
5. Place each piece of paper into separate beakers. [Do not let the paper touch the sides or bottom of the beaker.]
6. The liquid will drag the colors up the paper at different speeds. Let this continue at least halfway up the paper.
7. Observe the different components.

## **Case Analysis Part 1**

1. How did you identify the unknown?
2. Why did the inks show different absorbance patterns if they all appeared to be the same color?
3. Do you think you would have seen the same large variations in absorbance if all the samples had been red ink or all the samples had been blue ink instead of black? Why or why not?
4. What did you learn about colors from conducting Part 1 of this activity?
5. How can ink analysis help the Secret Service catch counterfeit bills?

## **Case Analysis Part 2**

1. Paper chromatography is a technique that can separate a mixture into its components as well as determine if a substance is a pure material or a mixture.



### ***The Ink is Still Wet***

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2. What colors did your group observe in each of the black ink samples?
3. Do the colors occur in the same order and in the same location on all the samples?  
Explain.
4. Did some ink samples not work? Why?
5. How are forensic scientists able to use ink chromatography to solve crimes?