Science and Technology of the Industrial World within the Classroom Walls: "The Crime Scene Investigator (CSI) Rainbow"

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Introduction

As educators we had, at least once in our career, students ask us questions such as: "Why do we need to know this?"; "Will this be on the test?" The fact that students even ask those kinds of questions proves the relevance that what we teach is not always as clear as it is to the educator. The main goal of this project is not only to answer the question "How Chemistry Works" but provide the students with an understanding of how even the simple concepts we cover in a high school course are applied in everyday life.

Unfortunately some times, when any of the sciences is taken out of context, the learning process tends to become a more passive one. Unfortunately by the time the students reach that point they are so defocused that they completely miss the relevance of what they are studying and they inevitably start asking the question: "Do we really need to learn this?"

Participating to the 2005 Princeton Regional Chamber of Commerce Educator Institute summer program has given me the "catalyzing energy" to start formulating the kind of program I always wanted to put together. I decided to call it: Science and Technology of the Industrial World within the Classroom Walls. The program is specifically designed to make the learning process more active. The various activities are intended complement rather than replace the more traditional learning processes with the ultimate goal of providing motivation and promoting curiosity and increasing the interest of the students in the subject.

A full implementation of the program will require the replacement of some of the laboratory activities in my Academic Chemistry course with self contained modules where the students are confronting a real problem from the perspective of a technician working in an industry based on science and technology. To accomplish this, each module is set in a virtual workplace where students learn to face real industry standard problems as they become integral and essential parts of the classroom experience. Within the workplace, each concept is presented in the context of the skills and problem solving techniques typical of a particular industry. Students will also work in groups sharing responsibilities and covering different roles just as it happens in the real work environment. This will enhance their sense of collegiality and their willingness of sharing information and acquiring knowledge from each other experiences. The laboratory activities also show the degree of interdisciplinary cross correlation between different sciences such as Chemistry, Biology, and Physics providing additional reasoning for student's motivation.

In particular, the visit to the New Jersey State Forensic Laboratories was the inspiration for the activity I am presenting in this lesson plan: "The Crime Scene Investigator (CSI) Rainbow". Most of the activities in the module dedicated to Forensic Science are performed in a virtual environment since the majority of the processes studied are either too complex of too sophisticated to be brought into the classroom environment. In the case of "The CSI Rainbow" a paper chromatography laboratory is presented to the students as a realistic example of a hands-on activity routinely performed during a forensic science investigation.

In summary, I hope that focusing on the application of realistic industrial procedures will increase the student's ability to understand the concepts and to appreciate their relevance in the "real" world they are about to merge into.

New Jersey Core Curriculum Content Standards Cross-reference

One of the main goals of the schools not only in the East Windsor Regional School District (EWRSD) but nation wide is to prepare the students to enter the workforce. The program is specifically designed to help the students become aware of the general workplace expectations and to practice methods to meet those expectations. A number of activities in the program promote the virtual workplace strategy. Students are asked to independently/in groups find or access relevant information from a variety of sources; design and carry out experiments; collect, organize and analyze their data; and arrive at a conclusion that help to solve a particular work related problem.

Besides clearly covering all the New Jersey Core Curriculum Standards 5.6 for "Chemistry", the nature of the project allows to extend its relevance to other two major areas of the New Jersey Core Curriculum Standards of Science: 5.1 – "Scientific Processes", and 5.4 – "Nature and Process of Technology".

In particular the project naturally relates to the section 5.1 – "Scientific Processes" – Building upon the knowledge and skills gained in preceding grades, by the end of Grade 12 students will:

A. Habits of Mind
   1. When making decisions, evaluate conclusions, weigh evidence, and recognize that arguments may not have equal merit
   3. Engage in collaboration, peer review, and accurate reporting of findings.
   4. Explore cases that demonstrate the interdisciplinary nature of the scientific enterprise.

B. Inquiry and Problem Solving
   1. Select and use appropriate instrumentation to design and conduct investigation.
   2. Show that experimental results can lead to new questions and further investigation

C. Safety
   1. Understand, evaluate and practice safe procedures for conducting science investigation.

Most of all, the project relates to the section 5.4 – "Nature and Process of Technology" - Building upon the knowledge and skills gained in preceding grades, by the end of Grade 12 students will:

A. Science and Technology

1. Know that scientific enquiry is driven by the desire to understand the natural world and seeks to answer questions that may or may not directly influence humans, while technology is driven by the need to meet human needs and solve human problems.

B. Nature of technology

1. Assess the impact of introducing a new technology in terms of alternative solutions, costs, tradeoff, benefits and environmental impact.

And finally, the most important point, resonating at the hart of the proposed project:

C. Technology Design

Plan, develop, and implement a proposal to solve an authentic, technological problem.

Impact on Student Achievement and Assessment of Effectiveness

I expect that progress will be quantified in two dimensions: student achievement and student perceptions. I expect to have an increase in student achievement at the specific course level as measured by increased average grades. I also anticipate an increase of students scoring proficient or better on the state of New Jersey HSPA exam. Finally, I expect this project to favorably impact students' perception of science, thereby encouraging them to continue with science throughout all four years of high school. This could lead to an increased request for more elective courses such as astronomy, geology, and microbiology thereby providing students the solid foundation that they will need to compete and succeed both at the university level and beyond.

Performance based assessment or often called authentic assessment will be used to measure what a student has learned by a student's actual performance of a task in a context that resembles real-life.

The tasks require students to incorporate a broad range of knowledge and use higher order thinking skills. Of course, for this kind of assessment to be most successful, students should have a clear idea of the criteria that will be used to asses their performance. These criteria will include:

- Scoring laboratory and activities reports based on widely shared standards rather than easily counted errors (as you would do in the extreme case of a multiple-choice test).
- Assess the broadness of the student's competences providing extra credit for extensive research beyond the general requirement of the assignment.
- Identify the student strengths and weaknesses providing formative assessments to help them develop a concept or a skill.
- Encourage, when possible, student's self assessment to increase sense of responsibility and motivation.
- Provide each student with a summative assessment on each project to help them measure their own proficiency in a specific concept or skill.

Name: ____________________________ Date:__________ Pd./day: _____

The Crime Scene Investigator (CSI) Rainbow

Introduction

Chromatography is a method used in the laboratory to separate certain homogeneous mixtures such as, for example a mixture of dyes in an ink solution. The various components of the mixture are separated base on the difference in their molecular structure, size and/or composition. In the field of analytical chemistry, often used in a forensic science laboratory, chromatography is used to conduct qualitative analysis (find out if a particular dye is linked to a particular crime through the identification of its components), and quantitative analysis (determine the relative concentration of the various components of the mixture, which often provides hard-evidence that could be used in court during a trial)

The chromatography technique of separation of homogeneous mixtures uses a stationary medium (in our case a strip of paper) and a mobile phase (in our case isopropyl alcohol). As base of the paper strip with the ink mark is placed into the solvent (alcohol) the mobile phase carries the molecules of the ink as it moves up the paper. The molecules of the different dyes composing the ink solution that are more strongly attracted to the alcohol (mobile phase) molecules will travel for a longer distance while the molecules of those dyes that are more attracted by the paper molecules (stationary phase) will stop sooner. As a result, the different dyes will separate out forming different bands of color (here is where the idea for the title of this activity comes from: CSI "Rainbow") forming a unique signature pattern in each chromatogram. The separation between the different bands of dyes is specific of each ink solution and allows its identification.

To provide quantitative data of the chromatography analysis we have to define the Retention Factors (R_F) as the distance traveled by the band of dye and the distance traveled by the solvent. This ration, in fact, is unique to each dye given the same experimental conditions of operation

Paper Chromatography Laboratory Activity

In this activity, paper chromatography is used to identify different types of ink stains found on different pieces of clothing used by each of the suspects and compare them to ink dye found on recovered stolen money from a bank.

Materials

- Pencil
- Wax pencil
- Ruler
- Isopropyl alcohol
- Four test tubes (20x150mm) in a rack with four stoppers
- Three strips of chromatography paper (1x16cm)
- Three different pens/markers labeled with letter A, B, C
- Chromatography paper with the ink trace from the crime scene

Prepare the Chromatography Samples and Perform the Chromatography Test

1. Using a **pencil** draw a horizontal line at 2cm from one end of the three strips of paper and label it starting line
2. Label with **pencil** three of strips “A”, “B”, and “C” and the fourth “CS” (for “Crime Scene”)
3. Draw a thin horizontal line of the correspondent ink on top of the starting line for each of the A, B, C strips
4. With the wax pencil draw a line on the test tubes at a distance 1.0 cm from the bottom of the tube and fill the each tube with alcohol up to the line you just marked.
5. Place the paper chromatograms into the tubes making sure they do not adhere to the edges of the tube. **Important**: the bottom of the paper should be immersed in the solvent but the ink line should not touch the solvent. Close the test tube with the stopper.
6. Leave the strips in the test tube for approximately 30-40 min and you will see the solvent slowly travel up the chromatogram dispersing a **“rainbow”** of colors.
7. One the chromatograms are developed extract them from the test tubes (all at the same time) and set them on a clean piece of paper.
8. Before the solvent dries out draw a line using the pencil at the highest point reached by the solvent and label it: “solvent line”. Now, you can allow the chromatograms to dry.
9. Tape the dry chromatograms onto the Paper Chromatography Data sheet included in this package
10. Now, look at the shape colors and pattern of the chromatograms and see if you can find one that is similar to that form the crime scene. If you have a positive match you might have just found important evidence that could be used to solve a crime

Quantitative Analysis: Determining the Retention Factors

1. To provide concrete and unequivocal evidence of an ink match you should now quantify your observations through a simple data analysis which will allow you to calculate the retention factors for each band of dye in the chromatogram that most resembles the one from the crime scene (we will call this the “suspect chromatogram”).
2. For each of the bands of dye in the “suspect chromatogram”, measure the distance from the starting line to the bottom of the band and record your data (call these measurements D_1, D_2, D_3, etc.). Now, measure the distance from the starting line to the solvent line (call these measurement D_S). Your measurements should be expressed in mm and you should always be careful with the significant digits in your data.
3. Calculate the retention factors taking the ratios: $R_F(1)=(D_1/D_S)$; $R_F(2)=(D_1/D_S)$; $R_F(1)=(D_1/ D_S)$; etc. Be very careful on retaining the correct number of significant digits in your calculation to preserve the original precision of your measurements.
4. Repeat step 2 and 3 for the crime scene chromatogram
5. Compare the R_F values of the bands from the crime scene to those of the “suspect chromatogram”. If the R_F values are similar within your measurement uncertainty, then, you can say that you have a positive match and you might have just found important evidence that could be used to solve the crime.

Determining the Retention Factors

You can use the following table to record the data and perform the analysis to determine the retention factors R_F. If you have inconclusive data form your qualitative analysis you must compare more than one suspect chromatogram to the crime scene chromatogram.

Dye Band #	Distance Traveled by the Band (mm) = $D_\#$	Distance Traveled by the Solvent (mm) = D_S	$R_F(\#)=D_\# / D_S$
1			
2			
3			
4			

Suspect ink: ____________ (indicate letter)

Dye Band #	Distance Traveled by the Band (mm) = $D_\#$	Distance Traveled by the Solvent (mm) = D_S	$R_F(\#)=D_\# / D_S$
1			
2			
3			
4			

Suspect ink: ____________ (indicate letter)

Dye Band #	Distance Traveled by the Band (mm) = $D_\#$	Distance Traveled by the Solvent (mm) = D_S	$R_F(\#)=D_\# / D_S$
1			
2			
3			
4			

Crime scene ink: ____________

Summary and Conclusions

After qualitatively comparing the chromatograms answer the following questions explaining your answer to prove your argument.

- Do you think you have a matching pattern with the crime scene chromatogram? Which one (give letter) and why? Explain your argument.
- What can you conclude about the suspect with your qualitative analysis?
- Which of the suspects can be excluded just looking at the patterns?
- Do you have similar patterns in the suspect chromatograms that also resemble the crime scene chromatogram? If you answer yes to this question you definitely need to wait until you measure the retention factors R_F to possibly identify the suspect
- Why do molecules of different dyes move further than others on a chromatogram during the same amount of time?
- If you were hired as an expert witness in a trial, how would you make your case based on the ink chromatography analysis you performed? To make a strong case YOU MUST include a quantitative analysis (determination of the retention factors R_F)at this point **<u>Use the back of this paper to make your case</u>**