Problem Based Learning: Forensic Chemistry

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Abstract
Problem–based learning (PBL) engages first year high school chemistry students through meaningful context. We designed a PBL lesson based on chemistry learners' interests, curriculum standards and context. The PBL project is a forensic chemistry unit, whereas, the students must be certified on various laboratory techniques and then are given a crime scene to investigate as a team. The crime scene includes an unknown liquid, unknown white powder and an ink sample to identify. Student teams then present their evidence and identity of the unknowns at a mock "court" day.

Keywords
Problem-based learning, PBL, chemistry, forensic, laboratory, unknown liquid, white powder

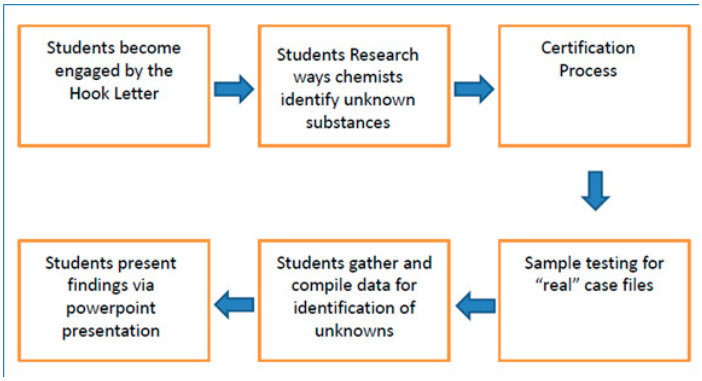
INTRODUCTION

Problem-based learning is founded on the idea of students becoming engage by doing relevant and reality based curriculum. Chemical forensic analysis from a crime scene fits the criteria. Students work in groups of three to four and collect data for analysis of a white powder, clear liquid, and an ink sample by completing seven different experiments/tests. To identify the liquid three tests are performed: they are melting point, chemical indicators, and solubility. The liquid is identified by using a FTIR spectroscopy, measuring the density, and boiling point. Paper chromatography is used to match the unknown ink. The students are first trained for each test and then later become a certified "expert" in three or four of the specific tests. When the certification is completed the forensic team receives their "official" crime case to analyze. Students gather and compile data for identifications of unknown samples in the crime. Students are given a "court" data to present their team's findings via a power point presentation.

PBL USING CHEMICAL FORENSIC ANALYSIS

High school chemistry students meet the problem for the PBL unit by reading a letter from the director of the local crime lab. In the letter it explains to the students why their help is needed. We present the local crime lab being overwhelmed with samples and are developing pilot programs for high school students to test samples. The students define the problem by researching laboratory techniques which can be used to identify white powders, clear liquids and ink samples (Figure 1). Figure 2 shows a more detailed timeline of the project the students will complete. With the guidance of the instructor they determine seven different experiments.

Figure 1. Overall Project Design and Flow



Station 1: Density

Students measure the density of 3.0 ml of their unknown liquid sample. They first weigh an empty graduated cylinder and record the mass. Then they measure 3.0 ml of sample and weigh the cylinder again. The mass of the liquid is found by taking the difference in the mass. Students then use the density equation and divide by the 3.0 ml volume to find the density of the liquid. They compared their density to a list of known densities.

Station 2: Fourier Transform Infrared Spectroscopy

A Fourier Transform Infrared Spectrometer (FTIR) was borrowed from Purdue University through the Science Express Program. The Science Express Program allows high schools to borrow specialized lab equipment for free. Students are trained on the instrument and run liquid unknown samples with

Figure 2. Timeline for Project

PBL Event	Forensic	Time Frame
Meet the problem	Hook the letter from the crime lab director	15 min
Define the problem	Discuss the chemical analytical techniques to determine unknown substances	25 min
Plan for and information gathering	Students research techniques	1 class day
Information gathering (groups)	Students are trained to do the experiments and collect data	2 class days
Information gathering (individually)	Students choose three or four of the experiments to become experts and earn certifications	2 class days
Share information	Receive crime case to analyze sample	2 class days
Determine the best-fit solutions	Compile data to determine the identity of unknown samples from the crime scene	2 class days
Prepare for presentation	Prepare PowerPoint with data from each experiment to provide evidence	2 class days
Present the solution	Students present the evidence and conclude the identity of unknown liquid, white powder, and ink at the "court date" based on their analysis	1 class day
Debrief the problem and the process	Instructor reveals the identity of the unknowns	Same day as "court day"

teacher supervision. They identify peaks and record the wavenumbers of prominent peaks, then compare their spectrum to the spectrums of known samples.

Station 3: Boiling Point
Students measure the boiling point of their unknown liquid using a hot water bath. Special care was taken to make sure that each unknown had a boiling point under 100 º C. Students suspended a test tube with unknown sample into a beaker of water. They heated the beaker of water slowly while monitoring the temperature of the test tube. Once the unknown liquid began to boil, they recorded the temperature and compared it to a known set of data.

Station 4: Melting Point
Students place a small amount of unknown powder into a mortar and pestle and grind until it is a fine powder. Then they load a capillary tube with a small amount of sample and place in the melting point apparatus. The digital melting point apparatus was also borrowed from Purdue University through the Science Express Program. The students then record temperature when the sample has melted and compare results to the reference sheet and find a possible match.

Station 5: Chemical Indicators
Students are given a white powder to analyze. They place a small sample of unknown into a well plate. Add 1 to 2 drops of several different chemical indicators and stir. Students will record the color changes (if any) and compare results to the reference sheet to find a match.

Station 6: Solubility Test
In three separate test tubes measure 10 ml of distilled water, ethyl alcohol and cyclohexane. Students place a pea size sample of unknown white powder into each and shake for 3 minutes each. Record the data as soluble, slightly soluble or insoluble for each. Students then compare the results to the reference sheet to find a possible match(s). This test is not definitive, but does narrow the possible matches.

Station 7: Paper Chromatography
Students are given an ink sample to analyze using paper chromatography. Students use water is the mobile phase to separate the different colors in the ink. They

then compare their findings to known chromatography samples.

CONCLUSION

After the students gather all the data, they present their findings at a "court date" as if they were real forensics scientist. Students are partially scored on their accuracy in determining the identity of the unknown substances. Each student has a role and must fulfill their role in order to have success. The project, as a whole, covers an area in the curriculum that can often be hard to engage students. This alternative approach allows students to learn about chemical and physical changes, properties of matter, and density in a new and exciting way while covering the state standards related to these topics. The Indiana State Standards covered include:

- C.1.1 Differentiate between pure substances and mixtures based on physical properties such as density, melting point, boiling point, and solubility.
- C.1.2 Determine the properties and quantities of matter such as mass, volume, temperature, density, melting point, boiling point, conductivity, solubility, color and designate these properties as either extensive or intensive.
- C.1.3 Recognize indicators of chemical changes such as temperature change, the production of a gas, the production of a precipitate, or a color change.
- C.1.26 Describe physical changes and properties of matter through sketches and descriptions of the involved materials.
- C.1.27 Describe chemical changes and reactions using sketches and descriptions of the reactants and products.

Students have had great success with this project and the students show a high level of engagement. We have had very positive feedback from students in regard to this lab activity; students really seem to enjoy what they are studying. In today's society, it is becoming harder and harder to engage students. This project is successful because it both engages students and covers the needed curriculum.

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REFERENCE

Problem-based Learning, Illinois Mathematics and Science Academy, http://www.imsa.edu