Supplementary Information

A Sustainability Approach to Inquiry-Based Experiential Chemistry Education in Pre-College Programs

Yalinu Poya*[a]

Momentum Lab: Connect Care: Technology in Human Health

Resources and Set-Up

The activity utilized a range of materials designed to create an immersive and authentic forensic investigation environment while emphasizing ecological processes such as decomposition. The setup included clipboards, pens, and paper for note-taking, along with UV lamps and tonic water to simulate blood for fingerprint and fluid analysis. A leopard model represented the victim, accompanied by a dog collar and a small blanket to mimic realistic crime scene conditions. Additional evidence items included a weapon marked with simulated bloody fingerprints, a hairbrush containing strands of black human hair, and insect models placed on the leopard's body to illustrate insect succession during decomposition. Insect succession charts were provided to assist students in estimating the time of death. For fingerprint analysis, students were given posters displaying ten fingerprints and a fingerprint feature guide attached to their clipboards. DNA analysis was represented through mock samples of blood and saliva contained in plastic tubes, alongside fabricated agarose gel electrophoresis results and DNA profiles for comparison. Skeletal analysis was supported by a poster of skeletal structures and a set of bones. For suspect identification, posters of the 6 main suspects were displayed.

Activity Structure and Workflow

The CSI activity had 6 stages, and each stage represented critical components of forensic investigation. Below are the stages and what they each entailed.

- **Stage 1 "Setting the Scene":** Students were divided into pairs to work together as a team. Students observed the crime scene and the preliminary evidence that was prepared. The evidence displayed on the crime scene where Leo the leopard's decomposed body, blood splatter, Leo's collar, the weapon with fingerprints, and a hairbrush with hair follicles.
- **Stage 2 "Help! We found the Body.":** On the leopard's body, there were insects. Students use insect succession charts to estimate the time of death and discuss the ecological processes of decomposition.
- **Stage 3 "Finding the Perfect Match – Fingerprint Pairing"**: Students used UV lamps to analyze the murder weapon. They compared the fingerprints to six suspects and used analytical reasoning to reinforce pattern recognition.
- **Stage 4 "Is it Leo? Who is the Killer? Let DNA Profiling Tell Us"**: Students analyze the blood splatter using DNA analysis techniques to confirm that the body belonged to Leo the Leopard, and they also use the hair follicles from the crime scene to collect a DNA profile. Students interpreted the agarose gel electrophoresis results to confirm identity and link suspects to the crime scene, illustrating molecular and chemical principles.
- **Stage 5 "Bone Zone"**: Students studied bone samples and bone charts to understand how they are analyzed at crime scenes.
- **Stage 6 "Who Did It?"**: In their pairs, students synthesized their findings and presented a narrative reconstruction of the crime, and identified the culprit from a list of 6 top criminal suspects.

Impact Lab: Sustainable Cities: Climate Resilience for a Better Future

Day 1: Climate Change and Rising Sea Levels

Resources and Set-Up

The ice breaker activity involved a variety of small colored balls and student volunteers to mimic the greenhouse effect. For the ocean acidification demonstration, the materials required were bromothymol blue indicator solution, water, and carbonated water for demonstrating pH changes, and baking soda and vinegar as common reagents for generating carbon dioxide. A tea light candle and matches were used to illustrate carbon dioxide (CO_2) production from combustion. Students worked with plastic cups, flasks, and graduated cylinders for solution preparation and

measurement, and straws to blow CO_2 into the solutions. For the sea-level rise experiment, trays were used to represent coastal landscapes, rulers for measuring water levels, blocks of ice to simulate glaciers and ice on land, modelling clay to portray land, salt water to mimic the ocean, and heat lamps to serve as a proxy for solar radiation. To model a suitable sea wall for coastal resilience, Play-Doh and modelling clay were used to construct an effective sea wall, trays for coastal landscapes, water for the ocean, and plastic lids to generate waves. Additional items such as seashells, pebbles, miniature trees, and human and animal figurines were incorporated to create realistic coastal models for the sea wall design challenge. Flip charts and colored markers were used for designing and also to record their observations.

Activity Structure and Workflow

Table S1 presents the activity structure for the Climate Change and Rising Sea Levels session, outlining demonstrations, experiments, and design challenges, and their time durations.

Table S1: Activity structure for the Day 1 session.

Activity	Description
Ice-Breaker Activity	Role-play showing the greenhouse effect: Earth and greenhouse gases intercept and return sunlight, illustrating heat trapping and increased warming. (10 minutes)
Introduction and Discussion	The session began with an introduction and an open discussion on the fundamentals of climate change and the role of greenhouse gases. (10 minutes)
Ocean Acidification Demonstration	The author conducted 3 experiments for students to observe. Firstly, students observed how CO_2 from human breath and carbonated water alter pH. Students experienced how CO_2 is produced through the reaction of baking soda and vinegar, and examined the effect of CO_2 produced by a candle flame on an indicator solution. (30 minutes)
Sea-Level Rise Experiment Design	Students got into pairs and designed an experiment to investigate the impact of melting ice on sea-level rise, focusing on comparing land and sea ice. The question they were required to address through the experiment that they designed was "Where is most of Earth's ice, on land or in water, and which type makes sea levels rise when it melts? (15 minutes)
Sea-Level Rise Experiment	Students executed their experiment to compare the effects of land ice versus sea ice on water level, reinforcing concepts of climate change. (20 minutes)
Sea Wall Design Challenge	Students were given a sea wall design challenge to construct and test a model sea wall to explore strategies for coastal resilience and apply engineering principles to sustainability challenges. (30 minutes)
Debrief and Reflection	Students presented their models, showcased their approach to sea wall design, and discussed broader implications for coastal cities in the context of climate adaptation. (15 minutes)

Day 2: Urban Heat Islands and Soil and Water Health

Resources and Set-Up

The materials used for this session were standard microscopes (400x magnification), microscope slides, and droppers for observing soil and water organisms. The soil and water samples were prepared a day before the lesson and were presented to the students. The soil samples were treated with organism extractor solutions to separate, preserve, and concentrate soil microorganisms; meanwhile, water samples were exposed to air and placed in indirect light. For nitrogen testing, students used sample trays and colour charts to assess nutrient levels in soil samples. Additional laboratory equipment, such as filter funnels, filter paper, and pipettes, was used for runoff experiments and nitrate measurements. Large reference charts showing common soil and water microorganisms were also displayed for students to identify organisms in their samples.

The soil samples were collected from locations on the Wentworth Institute of Technology campus: outside the Annex building, north of the quad, south of the quad, outside the Wentworth building, and in front of Rubenstein Hall. The water samples were collected from the Merrimack River, the Muddy River, a local pond, and the ocean.

Activity Structure and Workflow

Table S2 highlights the sequence of activities in Day 2: Urban Heat Islands and Soil and Water Health, activity descriptions and their respective time durations.

Table S2: Activity structure for the Day 2 session.

Activity	Description
Introduction and Discussion	The session began with an introduction to soil as a living system, emphasizing its role in nutrient cycling and ecosystem health. Water as a system was also discussed (10 minutes)
Microscopy Exploration	Students got into pairs and were given a standard microscope and shown its different components and how to use it efficiently. (10 minutes)
Soil Organism Analysis	Students observed soil biodiversity under the microscope, examining organisms in soil from the different samples. Students recorded their observations and answered questions from a provided worksheet. (30 minutes)
Water Organism Analysis	Students analysed water samples from the different sources to determine organism presence and diversity. Students recorded their observations and answered questions from a provided worksheet. (30 minutes)
Nitrogen Fertilizer Testing	Students compared fertilized and unfertilized soils to assess nutrient levels and understand nitrogen's role in soil health. Students measured nitrate concentrations in runoff to evaluate the impact of fertilizer use on soil and aquatic systems. (30 minutes)
Debrief and Reflection	Students presented their observations and discussed soil health, sustainable agriculture, and the effects of human activity and climate change on Earth's biosphere. They also discussed how aquatic organisms respond to changes in water properties such as dissolved oxygen, pH, temperature, and nutrients. (15 minutes)

Day 3: Biodiesel Production and Evaluation

Resources and Set-Up

The materials required for this session were vegetable oil and methanol as the primary reactants for biodiesel synthesis, along with potassium hydroxide (KOH) and sodium hydroxide (NaOH) pellets as catalysts for the transesterification process. Students used standard laboratory glassware such as test tubes with stoppers and parafilm, beakers, and pipettes for handling and mixing reagents. Hot plates were used to heat the oil during synthesis, while thermometers and ice baths were used to monitor and control temperature throughout the procedure.
The detailed activity structure and workflow for the Biodiesel Production and Evaluation session, including time allocations for each component, is provided in the Supplementary Information (Table S3).

Activity Structure and Workflow

The activity structure and workflow, and time duration for each component for the biodiesel session are summarized in Table S3.

Table S3: Activity structure for the Day 3 session.

Activity	Description
Introduction	Overview of alternative fuels and biodiesel, highlighting sustainability, its importance, and the promise of transitioning from fossil fuels to green energy. (10 minutes)
Safety Briefing	Safety presentation, biodiesel production, and precautions for handling flammable materials such as methanol and caustic basic catalysts (KOH and NaOH). (10 minutes)
Synthesis Activity	Students conducted biodiesel synthesis by heating vegetable oil, mixing it with methanol and a catalyst (they had the option to use either the KOH or NaOH), then shaking and allowing the mixture to settle to complete the transesterification process. (45 minutes)
Quality Testing	Students conducted solubility (3/27), emulsion stability, and cloud point determination tests to evaluate biodiesel properties and performance. (30 minutes)
Evaluation and Discussion	Students shared results, compared experimental conditions, and reflected on biodiesel's advantages and disadvantages as a sustainable energy source. (15 minutes)

Impact Lab Exit Survey

Section 1 — Academic Program Feedback
1. Your academic program: _____

2. Interactions with faculty in your academic program:
Extremely Satisfied
Somewhat Satisfied
Neither Satisfied nor Dissatisfied
Somewhat Dissatisfied
Extremely Dissatisfied
3. When thinking about your ACADEMIC PROGRAM, what aspects did you enjoy?
_____
_____
4. When thinking about your ACADEMIC PROGRAM, what do you think could be improved?
_____
_____
Section 2 — Program Experience & Engagement
5. Overall, what was your favorite part of ImpactLab?
_____
_____
6. Please indicate how likely you are to apply to a program at Wentworth Institute of Technology in the future:
Extremely Likely
Somewhat Likely
Neither Likely nor Unlikely
Somewhat Unlikely
Extremely Unlikely