Lesson Title	Creation of a Standard using a Spectrophotometer and Data Application to Estuary Geochemistry
Length of Lesson	1-3 Days
Created By	Henry Stauffenberg IV
Subject	Earth Science
Grade Level	9-12 (Environmental Science)
State Standards	Chemistry: 1 g, d; Environmental: 1 a, b, 2 b; Geology: 2 f.
DOK Level	Environmental: 3; Chemistry: 2; Geology 2
DOK Application	Organize, graph, compare, interpret, investigate, formulate, connect, analyze, design, assess, draw conclusions
National Standards	9 – 12 A: Inquiry; B: Physical Science; C: Life Science; D: Earth Science; E: Science and Technology
Graduate Research Element	Quantitative treatment and analysis of data followed with application of concepts to real life research scenarios. Incorporating graduate research about sediment and mercury cycling.

Student Learning Goal:
The purpose of this lesson is to promote student skill proficiency with a spectrophotometer and the importance of a standard when investigating unknown solution sample concentrations. Student's will learn how to inquire, investigate, apply big picture analysis concepts, and make connections between the ecosystem and human impact along with other chemistry/geology applications. The goal is to promote understanding about the complexity of open system ecosystems and incorporate graduate research about sediment and mercury cycling. Optional: constructing models (estuary or other similar ecosystems) based on real data and applied concepts.

<u>Mississippi State Standards</u>
Chemistry: 1: (g) Collect, analyze, and draw conclusions from data to create a formal presentation using available technology; (d) Organize data to construct graphs (e.g., plotting points, labeling x-and y-axis, creating appropriate titles and legends for circle, bar, and line graphs), draw conclusions, and make inferences.

Environmental: 1: (a) Conduct a scientific investigation demonstrating safe procedures and proper care of laboratory equipment; (b) Formulate questions that can be answered through research and experimental design. 2: (b) Explain the flow of matter and energy in ecosystems.

Geology: 2: (f) Develop a logical argument to explain how geochemical and ecological processes (e.g., rock, hydrologic, carbon, nitrogen) interact through time to cycle matter and energy, and how human activity alters the rates of these processes (e.g., fossil fuel formation and combustion, damming and channeling of rivers).

National Science Education Standards of Content 9 – 12

A: Inquiry: identify questions and concepts that guide scientific investigations

- Students should formulate a testable hypothesis and demonstrate the logical connections between the scientific concepts guiding the hypothesis and the design of an experiment. They should demonstrate appropriate procedures, a knowledge base, and a conceptual understanding of scientific investigations.

B: Physical Science: structures and properties of matter with respect to spectrophotometric analysis

- The physical properties of compounds reflect the nature of the interactions among its molecules. These interactions are determined by the structure of the molecule, including the constituent atoms and the distances and angles between them.

C: Life Science: Interdependence of organisms and organization in living systems

- Organisms both cooperate and compete in ecosystems. The interrelationships and interdependencies of these organisms may generate ecosystems that are stable for hundreds or thousands of years.
- As matter and energy flows through different levels of organization of living systems-cells, organs, organisms, communities-and between living systems and the physical environment, chemical elements are recombined in different ways. Each recombination results in storage and dissipation of energy into the environment as heat. Matter and energy are conserved in each change.

D: Earth Science: geochemical cycles

- The earth is a system containing essentially a fixed amount of each stable chemical atom or element. Each element can exist and cycle through different chemical reservoirs. Each element on earth moves through reservoirs in the solid earth, liquid earth, and atmosphere.

E: Science and Technology: Understanding about science and technology using a spectrophotometer.

- Scientists in different disciplines ask different questions, use different methods of investigation, and accept different types of evidence to support their explanations. Many scientific investigations require the contributions of individuals from different disciplines, including engineering. New disciplines of science, such as geophysics and biochemistry often emerge at the interface of two older disciplines.

Materials Needed (supplies, hand-outs, resources):

The following is for 30 students divided into groups of four; One or more spectrophotometers; water, assorted food coloring (unless you choose a real chemical reacted with indicator solution), cuvettes, 8 100ml volumetric flasks or graduated cylinders (If using serial dilution technique), 24 100ml beakers, 8 pipettes or eyedroppers, 8 stir bars and weigh scales (optional), computer with excel program (optional), map of an ecosystem (preferably Weeks Bay, Alabama from my research with site locations labeled), 4 or more pre-made printed standards (Fe, Mn, H_2S, other geochemical), 4 or more sets of pre designed absorbency results (to be calculated by students for concentration values) with respect to pre-made given standards, and finally other fluvial/watershed/sedimentary/other data specific to map site (optional for students may potentially look this up).

Lesson Performance Task/Assessment:

- Completion of lab activity standard (graphed with linear equation) and quantified concentrations of given unknown solutions (using linear equation). Must use spectrophotometer and serial dilution technique or direct molar calculations technique when preparing standard.
- Completion of handout involving conversion of given absorbency readings using given pre-made geochemical standards. Must use linear formula associated to each standard.
- Completion of Inquiry sheet (Big idea questions), pertaining to the concentrations the students calculated, supplied with a site map and other research pertinent data about the map and surrounding area.
- Development of a logical and insightful discussion about inquiry sheet and questions that students were required to write down pertaining to application of concepts and big ideas not covered by inquiry sheet.
- Optional: completion of an ecosystem model (or investigative research homework assignment) utilizing the discussion, organized data, internet/ library, and applied concepts.

Lesson Relevance to Performance Task and Students:

- To gain lab practice and experience using a spectrophotometer, volumetric glassware, serial dilution technique or direct use of molar calculation formulas, graphing linear standard equation to be used with concentration calculations for unknown samples, and to understand how important precise creation of standards must be and their usefulness for statistical analysis of samples.
- To interact with real research data and gain insight into the role of a geochemist
- To facilitate student inquiry and ability to apply concepts by asking critical questions based from organized collective data; to keen investigative skills by making connections, comparisons, and looking at the big picture (type of analysis).
- To develop the skills of logical argument and discussion. To facilitate both group work and independent study.
- To connect with independent research and be able to do describe (in general terms) what their data means/understanding of an open complex ecosystem in there own words.

Anticipatory Set/Capture Interest:
Start by a role play pep talk, introduce a real world problem and establish that everyone is a geochemist starting their first day at work. Then go into training exercise showing uniquely colored solutions of unknown concentration (made from food colorings) that students will have to work with in lab. Start by letting students play with their spectrophotometer(s) on different wave lengths settings with different color samples before splitting into groups and assigning colored samples to each group (group 1 blue samples, group 2 red samples, ect.)
Optional: Start by asking a series of thought provoking questions and gain student intrigue. Then establish that they will be the ones to find out; for example, why is toxic mercury contaminating our seafood? Why is it greater in predatory fish? What is the source and are humans to blame? Then give them real data to work with and promote a discussion; and with any luck, may turn into a spirited class debate.

Guided Practice:
Start by briefly explaining the basics of a spectrophotometer in how it works and how to use one. Then explain lab expectations, introduce standard creation and concentration calculation (based on absorbency) concept, and explain or demo serial dilution technique used to create standard. The serial dilution technique involves taking a 8Molar 100ml flask, cutting it in half by pouring into beaker, and filling beaker with 50ml water to make beaker solution 4Molar; the process is repeated until 1Molar is achieved. If necessary a quick review on calculating moles or linear graphing may be implemented. Then let students work with spectrophotometer(s) and walk around room to provide advice and guidance when and if needed. It may be necessary to show students how to graph their absorbency data points using excel and have them mimic what you do when it comes to creating and application of a linear equation. The true absorbency conversion understanding will come in a worksheet after the lab activity and, providing the students listened through the lab walkthrough, it should be no problem for them to use other pre selected linear standards to covert given absorbencies.
After the lab and worksheet, guide the students by introducing a real world problem (perhaps mercury contamination in seafood of Weeks Bay Alabama). Define their role as a geochemist and explain what they are going to do (observe, describe, process, and interpret) using the data they have calculated and new data that you will provide; guiding students with their organization of calculated data and addition of new material (map, sedimentary data, ect.). It may be appropriate to have students do some additional data collection (on the ecosystem of study) from the internet or other provided sources.
For the questionnaire and class discussion to follow it will be necessary for the instructor to start off with some questions/hints, or teasers, to help stimulate group discussion, student inquiry, and work on a short big idea questionnaire asking students to use their collected data to answer the following questions and write down questions of their own, see attached document for specific big idea questions. After giving time for students to work on the questionnaire among themselves it is the role of the instructor to guide the class discussion and make sure that the big idea questions are covered, the right questions

are asked, and stimulating student involvement and perhaps providing a mini lecture to ensure application of concepts and tying together of activities/research with the goals of the lesson.
After the discussion the lesson can be finished or continued by assigning homework to explore more investigative issues, create sedimentary/ecosystem models, or other student based activities taking their understanding to the next level or transition into next subject. For example, researching the microbial relationship or human impact factor.

Independent Practice:
Students work in lab creating standards and using spectrophotometer in groups and then breakup to complete a corresponding independent worksheet applying use of given standards with equations to calculate concentrations of given absorbencies.
Either before or after discussion the students are sent on their own to use resources to attain data about the ecosystem topic or complete homework assigned related to the day(s) activities. Otherwise everything that is detailed can be independent or in a group setting, there is enough flexibility depending on instructor preference and class size.

Remediation and/or Enrichment:
Remediation: individual IEP, partner with helpful student, shorten assignment(s), make lesson more walk through intensive.

Enrichment: Have students perform more statistical work with created standards beyond a linear regression. Have them explain why a scatter plot is better used than a linear plot when it comes to graphical analysis. As for discussion feel free to ask the harder concept questions or provide less data and give students more time to find the needed material using available resources to answer questionnaire pertaining to big picture analysis/discussion. Have them create a short presentation describing and applying the data the have collected about the ecosystem in there own words; with respect to a topic such as human impact, interdependence of organisms, and more. Have them create a model to describe their data visually.

Check(s) for Understanding:
<u>In addition to assigned work from lesson</u>
Show or tell me how a spectrophotometer works? Given the following absorbency data graph the standard, generate the linear equation, and use standard to covert sample absorbency readings into concentration values.
Why is it best to have an R value above 0.90 in your linear equation? How would a poor standard skew results, lets say R value less than 0.70?
Why do sites in the top part of Weeks Bay have higher concentrations of geochemicals when compared to bottom?
Based on your collective data, is there any evidence of human impact?
Without knowing the geochemical concentrations of Weeks Bay could an accurate/ complete analysis take place?

Describe to me how Fe, S, C, and O_2 concentrations effect the sedimentary environment?

Closure:
Besides answering all assigned worksheets, and potentially the checks for understanding, closure will come from the wrap up of the discussion. The instructor will mention that there is no one answer for many of the problems discussed and lead into his next lesson that could easily be connected to Weeks Bay or anything covered in this lesson. Homework is an option and in the very least students should be provided an ending to the real world problem from the viewpoint of the instructor with mini lecture about potential future work and further connections into graduate research and how vital a role spectrophotometers play.

Possible Alternate Subject Integrations:

Physics: Using the spectrophotometer; light absorption, color spectrum, and material interaction with light on atomic and molecular scale, ultraviolet light spectrophotometers vs. visible light, Beer's law.

Chemistry: Using the spectrophotometer; indicator solutions, acids and bases effecting absorbency, chemical dynamics to color of substances.

Math: Linear regression, graphs, and statistical analysis of standards or sample data, Beer's law.

Teacher notes:
If using food coloring use the following wave length ranges for optimum light absorbance in samples.

Neon Blue: 562-600 nanometers
Neon Purple: 500-520 nm
Neon Green: 480-490 nm
Neon Red: 450-470 nm

For what ever ecosystem instructor chooses, like an estuary, be sure to have access to sediment profile data, surrounding watershed data, and other data available through online journals and pdfs. Instructor will have to do some research himself or find others who have research material that would be useful for ecosystem discussion.

Email Henry Stauffenberg (henrystauffenberg4@gmail.com) for more info on Weeks Bay not provided with this lesson plan