**Investigating Your Critical Zone**
An Application of the Scientific Method to Critical Zone Science for Students

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**Brief synopsis**

Intended Grade Level: 8th Grade, plus or minus one year

Time Required: One class period to introduce and set up, partial class time and homework for setting up experiments and conducting measurements, one class period to interpret and discuss results.

The Critical Zone is where life meets rock, from the top of vegetation down to the bottom of the groundwater.

Critical Zone science is an interdisciplinary science that draws upon the concept of Earth Systems but focuses on integration of knowledge across fields of study.

Students will choose/design an experiment to conduct, using materials from their own Critical Zone, collect data through time, and make interpretations based upon their results.

Students are asked to choose (or potentially create a hypothesis with approval) one of three main nonliving components of the Critical Zone (rock, soil, water).

**Educational Standards**

Next Generation Science Standards (NGSS)

**MS-ESS2-1**. Develop a model to describe the cycling of Earth’s materials and the flow of energy that drives this process.

**MS-ESS2-4**. Develop a model to describe the cycling of water through Earth’s systems driven by energy from the sun and the force of gravity.

**MS-ESS3-1.** Construct a scientific explanation based on evidence for how the uneven distributions of Earth’s mineral, energy, and groundwater resources are the result of past and current geoscience processes.

**Outcomes**

Knowledge/Experience: After completing the exercise, students will have a fundamental understanding of how scientific experiments are conducted. Furthermore, they will have an experience that geologic materials are dynamic and discover ways to observe these changes.

Skill sets acquired: Students will utilize inductive reasoning as well as experimentation to answer an initial question. Moreover, students will practice quantitative analyses by one or more accurate observations of the following: mass, volume, temperature, solution pH. In addition, students will gain practice with qualitative data such as visual observations or tactile estimations of material properties.

**Prior Knowledge**

Students need to know the scientific method, an introduction to Earth’s materials (air, water, soil, rock), and SI measurement units.

Foundational knowledge of the pH scale (acid vs base vs neutral).

Students should have prior experience using google sheets and making graphs to plot data. Graphing may also be done by hand.

**Questions, Hypotheses and brief Experimental Design for Students**

**Rock Question 1:** *Do rocks affect water in the Critical Zone?*

Hypothesis: Rocks in the Critical Zone influence stream water chemistry. Rocks collected by students will change the pH of water.

Experimental design: Rocks collected by students are submerged in water for a month and students collect data twice a week to determine if rocks affect the pH of the water.

**Soil Question 1:** *Do organisms affect water storage in the Critical Zone?*

Hypothesis: Plants and human activities increase the storage of water in soil.

Experimental design: Students will collect soil a forested area\*, a human-dominated area (backyard) and from a garden area as a control. Students will add water to soil in mason jars and determine how much water is stored over the month by measuring total mass twice a week.

\*For schools in nonforested areas, students may use a shrub or wildland area.

**Soil Question 2:** *How do soils affect water in the Critical Zone?*

Hypothesis: Soils in the Critical Zone influence the chemistry of water through interactions with minerals and organic matter. Soils collected by students change the pH of water.

Experimental design: Soils collected by students are submerged in water for a month and students collect data twice a week to determine if rocks affect the pH of the water.

**Water Question 1***: Does water chemistry change in the Critical Zone?*

Hypothesis: As water moves through the Critical Zone, its chemical properties change. Water collected at different stages will have a different pH.

Experimental design: Students will collect water twice a week from at least 3 different sources (rain, drive way runoff, streams, ponds) to determine if water pH changes during its movement through the Critical Zone.

**Water Question 2***: Do humans or plants affect water in the Critical Zone?*

Hypothesis: Water that interacts with vegetation and human systems, will look different and have a different pH.

Experimental design: Students will collect water from rain fall and either a human dominated area (street runoff, storm drain) or beneath a vegetated area (beneath a tree or shrubs) and compare the pH and visual characteristics.

**Materials and Methods**

**Rock Question 1: How does rock affect water in the Critical Zone?**

Materials:

* Four mason jars (16 oz ) per group or student
* Water
* 3 types of rocks collected by group or students
* pH test strips

Methods:

1. Students collect three types of rock that can fit inside a regular 16 oz mason jar.
2. Students weigh out and place 50 – 100 grams of rock into three of the mason jars. Jars should be labeled with the type of rock added.
3. Students add enough water to the three mason jars with rocks to submerge all surface. Students will also add water to an additional jar as a control.
4. Students measure the pH using pH test strips twice a week. Students should measure pH at least six times during the project and keep data on a provided sheet.
5. At the end of the project, plot the pH for each jar of rock and determine if the pH is different compared to the control.

Safety

Rocks should be collected under adult supervision from areas where permission can be obtained. Important care should be taken while working with the glass mason jars, particularly during handling (opening, closing, storing) for pH measurements.

**Soil Question 1: Do organisms affect water storage in the Critical Zone?**

Materials:

* Three mason jars (16 oz ) per group or student
* Water
* 3 types of soils collected by group or students

Methods:

1. Students collect three different types of soils (examples: garden, backyard, side of home, field) and remove any large pieces of rock or wood larger than a quarter in size.
2. Students weigh out and place 50 grams of soil into three of the mason jars. In addition, students should label the mason jars based upon the soil (Garden, Human, Forest) and weigh them before adding the soil.
3. Students add 100 grams of water to the three mason jars with soil and weigh them again.
4. Students measure the mass of the mason jars with the soil and water twice a week and keep data on a provided sheet.
5. At the end of the project, students will plot the mass of each mason jar of rock and determine if the pH is different compared to the control.

Safety

Soil should be collected under adult supervision from areas where permission can be obtained. Important care should be taken while working with the glass mason jars, particularly during handling (opening, closing, storing) for pH measurements.

To prevent soil messes, students should work with their soils in bins or on tarps. Regular spoons work as excellent soil spatulas.

**Soil Question 2: How does soil affect water chemistry in the Critical Zone?**

Materials:

* Four mason jars (16 oz ) per group or student
* Water
* 3 types of soils collected by group or students

Methods:

1. Students collect three types of soils (examples: garden, backyard, side of home, field), remove any large pieces of rock or wood larger than a quarter in size.
2. Students weigh out and place 50 grams of soil into three of the mason jars. In addition, students should label the mason jars based upon the soil (examples: garden, backyard, field).
3. Students then add 200 grams of water to fully submerge the soil and 200 grams to the empty mason jar as a control.
4. Students measure the mass of the pH of the water twice a week and keep data on a provided sheet.
5. At the end of the project, students will plot the pH of each mason jar of soil and water to determine if the pH is different compared to the pH of the control jar of only water.

Safety

Soil should be collected under adult supervision from areas where permission can be obtained. Important care should be taken while working with the glass mason jars, particularly during handling (opening, closing, storing) for pH measurements.

To prevent soil messes, students should work with their soils in bins or on tarps. Regular spoons work as excellent soil spatulas.

**Water Question 1: Does water chemistry change in the Critical Zone?**

Materials:

* Rinsed, previously used water bottles.
* pH strips
* plastic funnels (at least 3 inches in diameter)

Methods:

1. Students shall collect water to measure weekly. Students will collect water from various sources in the Critical Zone: rainfall, overland flow, streams, ponds.
2. Students can use previously washed water bottles for sample collection (soda and juice bottles are not recommended due to residual organic acids). Bottle labels should be removed and properly labeled with the type of sample collected.
3. To collect rainfall, students need to set up clean jars (water bottles are okay if jars unavailable) with funnels open to the sky at their home.
4. Students will measure the pH of the water collected. At the end of the project, students will compare the pH of the different samples and determine if the pH in streams and other surface waters are different than rain water.

Safety

Water sampling should be collected under adult supervision from areas where permission can be obtained. Students should avoid large water bodies (rivers, lakes, and oceans) due to drowning and falling hazards. Care should be taken while labeling samples to prevent accidental ingestion of the water sample.

**Water Question 2: Do humans or plants affect water in the Critical Zone?**

Materials:

* Three cleaned jars with narrow mouths.
* pH strips
* plastic funnels (at least 3 inches in diameter)

Methods:

1. Students shall collect water to measure pH weekly. Students will collect water from rainfall that interacts with human structures and plant canopy.
2. Students can use previously washed jars for sample collection (poorly cleaned jars bottles are not recommended due to residual organic acids). Jar labels should be removed and properly labeled with the type of sample collected.
3. To collect rainfall, students need to set up clean jars (water bottles are okay if jars unavailable) with funnels open to the sky at their home. One shall be directly beneath a plant, another in a location to catch run off from a building, and the last one in an open location away from plants and buildings.
4. Students will measure the pH of the water collected. At the end of the project, students will compare the pH of the different samples and determine if the pH of water that interacted with plants and human structures are different than rain water.

Safety

Water sampling should be collected under adult supervision from areas where permission can be obtained. Students should avoid large water bodies (rivers, lakes, and oceans) due to drowning and falling hazards. Care should be taken while labeling samples to prevent accidental ingestion of the water sample.

**Analysis of Data Results by Students**

1. What is the main question you are trying to answer?
	1. Students should be able to restate the question their experiment seeks to answer. It is also provided clearly provided in the worksheet.
2. Plot your data on an x-y plot. Please remember to use the time on the x-axis and your measured variable on the y-axis.
	1. Students will either use google sheets or hand plot their data on graphs to determine how things have changed.
3. What trends does your data show?
	1. Students should be provide a fundamental understanding of what is changing. For example, the water mass decreased with time, the water pH increased with time, etc.

**Discussion of Results by Students**

Use the space below to write a well-developed answer to your original hypothesis. Be descriptive and use examples from your experiment to highlight and explain. Do the results support the hypothesis? Explain why.

* Here the students should be encouraged to describe what was changing during their experiment and hypothesize how it was changing.
* Hypotheses for each experiment are provided in the work sheet, thus they can state if the results support the provided hypothesis.
* Although students do not need to know the exact physical or chemical mechanism, they should be able to state that rock, soil, or humans have affected how water moves through the Critical Zone.