

Title: Schoolyard Investigation on Agriculture Sustainability Unit

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Lesson One: Trial by Water

Age Group: 9th -12th grade

Lesson duration: One week

Year: 2009

Cost: *Approximately \$300 to purchase all materials needed for the three lessons*

BACKGROUND

Our school is employing the Environment as a Integrating Context (EIC) curriculum model, therefore all subjects must integrate the environment into their curriculum. Mathematics is a subject that can be used to explain the patterns that occur naturally in nature as well as to help interpret data collected. The tenth grade theme is Pollution/Recycling/Air and Water Quality. My goal is to create a school compost site to create a compost material suitable for the school garden. Prior to doing this, students will investigate the soil quality, reasons for composting, the various ways of composting, the different compost recipes and their purposes, and design an experiment to develop an optimal compost recipe to be used. This is lesson 1 of 3 lessons that investigate a unit on agriculture sustainability. These lessons start with an analysis of soil on the campus, to determining and investigating compost recipes, and will culminate in creating a student-managed, school compost site, that will be used to fertilize the school's garden.

GEORGIA PERFORMANCE STANDARDS (GPS) MATHEMATICS STANDARDS ADDRESSED

- MA2A6 Students will perform basic operations with matrices
- Add, Subtract, multiply, and invert matrices, when possible choosing the appropriate methods including technology.
- MA2D1 Using sample data, students will make informal inferences about population means and standard deviations
- Pose a question and collect sample data from at least two different populations
 - Understand and calculate the means and standard deviations of sets of data.
 - Use means and standard deviations to compare sets of data.
 - Compare the means and standard deviations of random samples with the corresponding population parameters. Observe that the different sample means vary from one sample to the next. Observe that the distribution of the sample means has less variability than the population distribution.
- MA2D4 Students will understand the differences between experimental and observational studies by posing questions and collecting, analyzing, and interpreting data.
- MA2P1 Students will solve problems (using appropriate technology).
- Build new mathematical knowledge through problem solving
 - Solve problems that arise in mathematics and in other contexts.
 - Apply and adapt a variety of appropriate strategies to solve problems.
 - Monitor and reflect on the process of mathematical problem solving.
- MA2P3 Students will communicate mathematically
- Organize and consolidate their mathematical thinking through communication.
 - Communicate their mathematical thinking coherently and clearly to peers, teachers, and others.
 - Use the language of mathematics to express mathematical ideas precisely.
- MA2P4 Students will make connections among mathematical ideas and to other disciplines
- Recognize and use connections of mathematical ideas.
 - Understand how mathematical ideas interconnect and build on one another to produce a coherent whole.
 - Recognize and apply mathematics in contexts outside of mathematics
- MA2P5 Students will represent mathematics in multiple ways
- Create and use representations to organize, record, and communicate mathematical ideas.
 - Select, apply, and translate among mathematical representations to solve problems.
 - Use representations to model and interpret physical, social, and mathematical phenomena.

OBJECTIVES

Students will learn to simple tests that use water to gauge aspects of soil quality and will use tables and charts to organize and display their collected data.

MATERIALS

General: lab manual (composition notebook); pencils; markers

Lesson 1: Trial by Water	Lesson 2: Compost Recipes	Lesson 3: Compost Happens
Water infiltration rings	Compost recipes WebQuest (teacher made)	3 2-liter bottles
Short pieces of board (8" – 2x4)	WebQuest has links to:	One bottle cap
Hammers	Compost recipe worksheet	Cutting blade
Plastic wrap	Composting at home fact sheet	Scissors
Water	"The Art and Science of Composting" article	Poke (darning needle)
Measuring cups or graduated cylinders	"Getting the Right Mix" article	Paper punch
Stopwatches	Internet access	Clear duct tape
Garden shovels	Large sheets of white paper	Drill (enlarge holes)
Soil samples: sand, clay soil, garden soil		Box top (stabilize bottle)
Clear plastic cups		Thermometers
Distilled water		pH strips
Labels		Camera
Permanent markers		

STUDENT-GENERATED INQUIRY QUESTIONS

How does soil quality affect plant growth?

What type of soil is best for a vegetable garden?

Is the soil located near the Arabia Mountain high school conducive to growing vegetables?

How can soil quality be improved?

SAMPLE HYPOTHESES AND PREDICTIONS

H: The soil found around Arabian Mountain High school is too aggregated and does not allow enough water to infiltrate it in order to sustain a vegetable garden.

P: If the soil found around Arabian Mountain High school is too aggregated and does not allow enough water to infiltrate it in order to sustain a vegetable garden, then it will not hold moisture as well as gardening soil.

HOOK:

Imagine that you are a tomato plant, what would you need to grow?

- What do plants need to grow?
- Where do tomatoes get their food?
- Where does the fertilizer go?
- If plants need sun and water to grow, if I just place tomato seeds on concrete and water them, will they grow?

Once students have determined that plants need soil, begin a discussion about types of soil needed for growing vegetables: how does the soil look and how should it feel. Place two large sheets of paper with the labels "LOOK" and "FEEL" and have them generate responses on each list to discuss.

Show students samples of different types of soil: sand, clay soil, garden soil. According to their criteria, have them determine which soil is best for gardening. Next, ask students if they think the soil found on the campus of Arabia Mountain High School is good for gardening? Ask if the soil is the same all over or if they think it will be different?

Discuss. Explain to students that they will be completing tests on the soil: a test for water infiltration and soil aggregation. The infiltration rate is a measure of how fast water enters the soil. Water entering too slowly may lead to ponding on level fields or to erosion from surface run-off on sloping fields. Aggregation is the soil's ability to remain intact despite the stresses from water. Disaggregation (soil break-up) promotes erosion. Using the samples presented earlier, demonstrate the test for cloudiness. Students return to their designated areas and complete four total tests of the soil.

PROCEDURE

Separate the students into groups of 3-4 to complete a school yard investigation on soil quality. Assign each group to a specific area of the school: school garden, athletic field, an undisturbed woodland, etc. Explain to students that they will be comparing their soil to store bought gardening soil. Have students generate a general hypothesis and a prediction question based upon what type of soil will be found in their assigned area.

Advance preparation: Make 6-inch tall infiltration rings from a plastic irrigation pipe and make small 2x4 boards. Decide where you want to conduct the tests. You want to compare at least two different soil situations. They can be different soil types or soils with different management or both. For example, on the school grounds you could test an athletic field, a flower bed, and, if available, land in crop production or a relatively undisturbed area of woodland. Send two groups to each area- one sunny and one shady.

EXPERIMENT

Test 1. Measuring infiltration in different soils

(This test is adapted from Chapters 3 and 2 of the USDA Soil Quality Test Kit Guide) Each group will be given an infiltration ring, plastic wrap, short pieces of board, hammers, and a gallon of water, and a graduated cylinder. Each ring will be the same diameter. The group can measure infiltration of their soil type in their assigned location; two tests in the shade and two tests in the sun, for a total of four tests.

1. Clear away sticks, stones, and other items that will keep the ring from being hammered into the soil from the area where the ring will be placed.
2. Place the ring on the ground, beveled side down. Lay the board across the top of the ring. Using the hammer on the board, drive the ring 3 inches into the soil (up to the line marked on the outside of the ring. Gently firm the soil right at the inside edge of the ring.
3. Lay a piece of plastic wrap over the ring so it completely covers the soil over the ring and extends up over the edge of the ring on all sides. This step is designed to prevent changing the soil surface when the water is poured on.
4. Measure the amount of water you needed to fill the ring to a depth of one inch (for the 6-inch irrigation pipe this will be 444 mL). Pour the measured water into the ring.
5. Remove the plastic by gently pulling it out, leaving the water in the ring, and begin timing as soon as the wrap is removed.
6. Using a stop watch, record the amount of time it takes for the water to infiltrate the soil (when there is no standing water but the surface is still glistening) on your data sheet. Depending on soil type, management, and conditions, this may take just a few minutes or over an hour. If there is not enough time to wait for all the water to infiltrate, have students estimate how much water is left on the surface after 15 minutes.
7. Repeat steps 3 to 6 in order to measure infiltration when the soil is already moist. If soil moisture is at or near field capacity the repeat test is not needed.

Test 2. Measuring aggregation (visually)

1. Drive the infiltration ring into the soil to a depth of about five inches. Use a trowel to dig around the ring and under the ring.
2. Carefully place the soil in a plastic bin; remove all vegetation and insects.
3. Ask the students to examine the soil and predict whether they think it will be stable in water.
4. Gently put a small amount of soil into a clear plastic cup.
5. Gently pour in enough distilled water to generously cover the soil sample.
6. Swirl the water in the cup for several seconds.
7. Observe the water. Ask students to note whether the water is clear, slightly (cloudy), or very cloudy.
8. Repeat steps 1 to 6 with soils from other locations in your area (two sunny and two shade)

DATA COLLECTION

In their field notebooks, students are to describe the area, whether they were in the shade or sun, and the look and feel of the soil. They are to record everything that is done (step-by-step). All data is to be recorded on the data sheet provided. Students will show steps necessary to convert the units from in/min to in/hr and use a calculator to check their answers.

ANALYSIS OF DATA

Students will identify the independent and dependent variables and create a scatterplot on graph paper. Students will determine if the relationship is linear or quadratic and use that information to determine a prediction equation for water infiltration at that point. Students will use the actual data and the prediction equation data to determine the mean and standard deviation of their data set and compare it to the data sets of others. Students will use this data to explain mathematically what they have concluded by using a hypothesis test to determine if the results support the hypothesis.

CONCLUSION

Students will use their observations, data, and numerical analysis to support or refute their hypothesis. Visual evidence must be supported by the numerical evidence. Students will create a presentation highlighting each step of the scientific process and explaining how their mathematical calculations are correlated to their results. Their presentation will include tables, graphs, and pertinent calculations. Students will be given 10 minutes to present their groups findings and the class will be given 5-10 minutes to pose questions to the group.

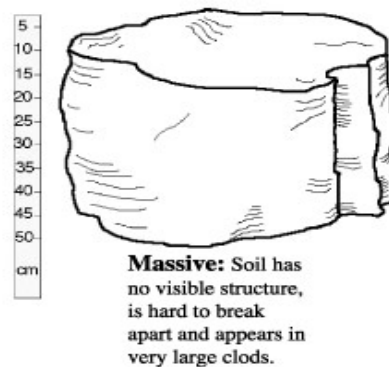
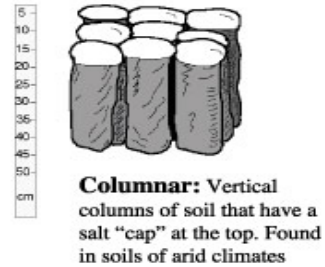
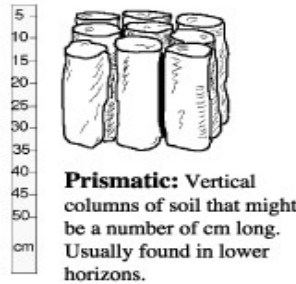
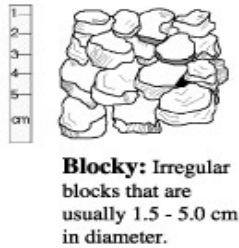
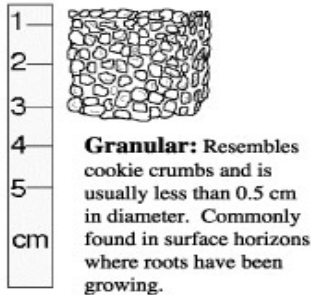
HW:

Students need to re-check their calculations and conclusions. Have students generate a list of five items to be planted in the vegetable garden and research the soil conditions needed to sustain those particular vegetables. Students must be prepared to defend their choice of vegetable using facts and data!

Soil Characterization Field Protocols

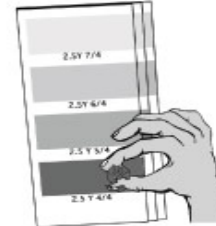
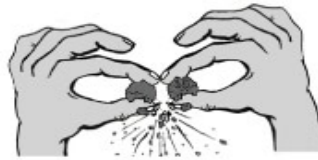
Soil Structure

Soil structure is the shape that the soil takes based on its physical and chemical properties. Each individual unit of soil structure is called a **ped**. Take a sample of undisturbed soil in your hand (either from the pit or from the shovel or auger). Look closely at the soil in your hand and examine its structure. Possible choices of soil structure are:



Soil Color

1. Take a ped of soil from each horizon and note on the data sheet whether it is moist, dry or wet. If it is dry, moisten it slightly with water from your water bottle.
2. Stand with the sun over your shoulder so that sunlight shines on the color chart and the soil sample you are examining. Break the ped.
3. Compare the color of the moist inside surface with the soil color chart.

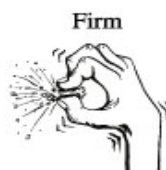


Note: Sometimes, a soil sample may have more than one color. Record a maximum of two colors if necessary, and indicate (1) the Main (dominant color) and (2) the Other (sub-dominant color).

Soil Consistence

Take a **ped** from the top soil horizon. If the soil is very dry, moisten the face of the profile using a water bottle with a squirt top and then remove a **ped** to determine consistence.

Holding it between your thumb and forefinger, gently squeeze the **ped** until it "pops" or falls apart. Record one of the following categories of soil consistence on the data sheet. (Repeat this procedure for each horizon in your profile.)



Soil Texture

Step 1 (Get and moisten sample)

Use the triangle to determine the soil texture of your horizon.

Place some soil from a horizon (about the size of a small egg) in your hand, and, using the spray mist bottle, moisten the soil. Let the water soak in and then work the soil between your fingers until it is the same moisture throughout. Once the soil is moist, try to form a ball. If the soil forms a ball, go on to Step 2. If the soil does not form a ball, go to Step 5.

Step 3 (Refine initial soil texture classification from Step 2 for relative amounts of sand and silt)

Wet a small pinch of the soil in your palm and rub it with a forefinger.

If the soil:

- Feels very gritty, go to E
- Feels very smooth, with no gritty feeling, go to F
- Feels only a little gritty, go to G

Step 4 (Test for loamy sand or silt)

If the soil:

- Forms a ball
- Forms **no** ribbon
- And is

H. Very gritty

Soil texture is: loamy sand
Soil Texture is complete.

Or

I. Very soft and smooth with **no** gritty feeling,

Soil texture is: silt
Soil Texture is complete.

Step 2 (Test for Clay)

A. If the soil:

- Is really sticky
- Hard to squeeze
- Stains your hands
- Has a shine when rubbed
- Forms a long ribbon (5+ cm) without breaking,

Call it a **clay** and go to Step 3.

Otherwise, go to B.

B. If the soil:

- Is somewhat sticky
- Is somewhat hard to squeeze
- Forms a medium ribbon (between 2-5 cm)

Call it a **clay loam** and go to Step 3.

Otherwise, go to C.

E. Add the word **sandy** to the initial classification.

Soil texture is (check one): sandy clay,

sandy clay loam, sandy loam

Soil Texture is complete.



C. If the soil is:

- Soft
- Smooth
- Easy to squeeze,
- At most slightly sticky,
- Forms a short ribbon (less than 2 cm)

Call it a **loam** and go to Step 3.

Otherwise, go to D.

D. If the soil forms a ball but **no** ribbon, go to Step 4.

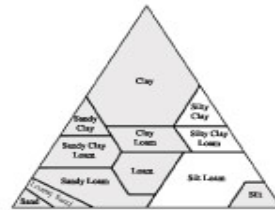


F. Add the word **silt** or **silty** to the initial classification.

Soil texture is (check one): silty clay,

silty clay loam, silt loam

Soil Texture is complete.



G. Leave the original classification of (check one):

clay, clay loam, loam

Soil Texture is complete.

Step 5 (Test for sand)

If the soil:

Forms no ball and falls apart in your hand,

Soil texture is: sand

Soil Texture is complete.



Free Carbonates

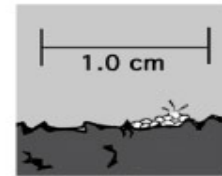
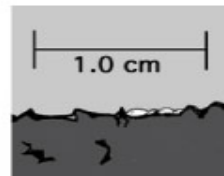
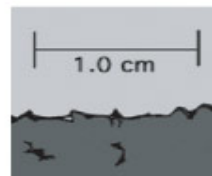
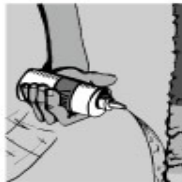
Working from the bottom of a profile up to the top, squirt vinegar in a straight line onto the soil. If free carbonates are present, they will "effervesce" or bubble when the vinegar reacts with them.

Record one of the following based on your observation:

None: you observe no reaction (the soil has no free carbonates).

Slight: you observe a slight amount of bubbling (the soil is coated with some carbonates).

Strong: you observe a strong reaction (many bubbles) (the soil has many carbonate coatings present).



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Infiltration (for 1 inch of water)								DATE:	
	Sample site	1st inch of water		(W) 1st Infiltration time (minutes)	* 1st Infiltration (in/hr)	2nd inch of water		(W) 2nd Infiltration time (minutes)	* 2nd Infiltration (in/hr)
		Start time	End time			Start time	End time		
1									
2									
3									
4									

* Conversion of infiltration time to inches per hour (in/hr); $in/hr = (1/W) \times 60$

NOTES:

Science Investigation Rubric

Criteria/Score	4	3	2	1	0
Question/ Hypothesis	Question (K-4) or hypothesis (5-12) has been thoroughly developed. Hypothesis is correctly stated with both variables identified	Question or hypothesis has been sufficiently developed with reasonable relevancy	Question or hypothesis is partially developed with some relevancy	Question or hypothesis has major flaws and limited or no relevancy	No attempt has been made
Score	–	–	–	–	–
Investigation Design	Investigation is a well-constructed test of the stated question or hypothesis. All of the developmentally appropriate components (materials, controls, procedure, safety) are arranged so that the investigation can be replicated exactly as described	Investigation is a reasonably constructed test. All of the components are reasonably arranged so that the investigation can be replicated.	Investigation is a partially constructed test. Some of the components are missing, making it difficult to replicate.	Test is not relevant to the question or hypothesis. Information is not sufficient to replicate investigation.	No attempt has been made
Score	–	–	–	–	–
Methods of Data Collection	Significant data has been collected in the most efficient and appropriate ways. Data is accurately recorded and displayed using the most relevant and organized methods	A reasonable amount of data has been collected in a sufficient manner. Data is recorded and displayed using organized methods.	A minimum amount of data has been collected. Data is recorded and displayed but may lack some organization.	Insufficient data has been collected. Data has not been recorded or displayed in an organized way.	No attempt has been made.
Score	–	–	–	–	–
Data Analysis: Conclusions, Inferences, & Recommendations	A precise statement of the investigation results relates directly to the question or hypothesis. Clear assumptions have been made from an accurate evaluation of the conclusion. Recommendations are clearly consistent with the findings of the investigation and provide an excellent defense.	A reasonable statement of the results shows a good relationship to the question or hypothesis. Reasonable assumptions have been made from the conclusion. Recommendations are reasonably consistent with the findings of the investigation and provide a good defense.	A statement of the results provides some relationship to the question or hypothesis. Assumptions are minimally supported by the conclusion. Recommendations are inconsistent with the findings and provide a questionable defense.	A statement of the results shows no relationship to the question or hypothesis. Assumptions are not supported by the conclusion. Recommendations show no relationship to the findings and provide a poor defense.	No attempt has been made
Score	–	–	–	–	–
Total Score	–	–	–	–	–

Lesson 2: COMPOST RECIPES(1-2 days)

Using the homework as a starter, write down the choices of vegetables that students have chosen. Have students vote for the top five and randomly select students to discuss the benefits of planting that particular vegetable.

HOOK:

Now that we have studied the soil and have determined it's ability to grow a vegetable garden and have chosen what veggies to plant, how do we fertilize the soil? (By the way, we will not be purchasing fertilizer)

- Think back to the ancient Egyptians, Greeks, Romans, Native Americans, and early settlers. How do you think they fertilized their crops? (generate a list and talk about feasibility)

Advance preparation: Create a webquest with the following links: Compost Recipes worksheet, Compost Recipes worksheet Key, Ohio State University Extension fact sheet "Composting At Home," and **pages 3 to 5** of "The Art and Science of Composting"and "Getting the Right Mix ".

1. Have the students complete a webquest on composting. They can read articles that discuss the history of composting, why composting is done, and how it is done. You may want to include articles that discuss the different types of composting recipes and their uses.
2. Assign each group an article. Have each group do a mini presentation discussion the facts in their article.
3. In pairs, students develop compost recipes for the examples on the worksheet. Explain to students that the recipes will be approximate. Why? First, because both moisture content and C:N (carbon to nitrogen) ratios will vary within the materials used. Second, because composting organisms can tolerate a range of moisture and C:N ratios.
4. Students discuss their recipes with the class.
5. Students create a compost recipe that can be used in the school's garden.
6. Students will use matrices to organize the ingredients and basic operations on matrices to determine the proper amount of ingredients to be used in their composting recipes. They will also use simple mathematics computations to ensure the proper amount of ingredients to be placed in their decomposition tower.

HW: Complete any unfinished calculations or recipe.

Lesson 3: Compost happens (2 days to establish the system and 6 weeks to observe)

HOOK

Ok, so now I know what kind of soil we are dealing with and how we can fertilize it, how can I decide which compost recipe will best meet our needs?

OBJECTIVE

Students will gain hands-on experience with composting.

Advance preparation: Determine if you want students to work in pairs or groups. Read the instructions to create and use a decomposition column using bottle biology: http://www.bottlebiology.org/investigations/decomp_main.html. These can be created prior to class or can be created in class by the students. Each pair can observe one column.

1. Create the decomposition column using the two liter bottles

2. **FILL:** Choose ingredients which can include leaves, grass and plant clippings, kitchen scraps, newspapers, animal manure and soil. Try adding fertilizer to your column, or water from a pond or river. How do you suppose differences in temperature, light or moisture will affect the decomposition process? Keep your column moist in order to observe more rapid decomposition. Avoid flooding your column or it will become waterlogged. This can create an **anaerobic** environment, or one completely lacking oxygen, in which certain microbes create particularly vigorous odors. The strongest odors arise from animal products such as meat and dairy products. Grapefruit rinds and grass cuttings can also produce strong odors. Why is this so? If you use food scraps, mix in plant matter such as leaves, twigs and dried grass to temper odors. Layering soil on top of contents also lessens the odor.
3. Increasing the number and size of air holes in your column will increase air exchange. How do you think this will affect decomposition? Keep holes small so fruit flies stay inside.
4. **OBSERVE:** Carefully observe what you put inside. In a notebook, describe the color, texture, smell and shape of everything you put in the bottle. Weigh everything before it goes into the column. Schedule column checks for at least once a week to record changes. Note changes in the column contents' height, color, shape, texture and odor. Hold a ruler next to the column to record changes in the height of the contents. Insert a thermometer from the top of the column to determine temperature changes. Can you figure out the rate of change? You can also test the pH of the leachate (the solution that drips through the column). Look for the appearance of any "critters," such as flies, beetles, slugs, millipedes, or snails. Decomposition Columns offer good opportunities for observation and description. Try using photographs or drawings to record changes. Write a story about what is going on in your column. What do you predict will happen during decomposition?
5. **EXPLORE:** What peaks your curiosity about decomposition? Consider questions that interest you, and design an experiment to look for evidence that could lead to a scientific explanation.

Estimated time: 2 hours to establish the compost system and at least 6 weeks of operation (10 to 20 minutes maintenance & observation per week).