Soil Comparison and Analysis

Subject Area(s)  Astronomy, Geology, Earth Science
Associated Unit  Comparative Planetology, Soil Comparison
Lesson Title  Soil Analysis

Grade Level  HS(9-12)
Lesson # _1_ of _1_

Time Required approximately 2 class periods

Summary
This lesson introduces the idea that scientists carefully measure and categorize characteristics of, among other things, soils of planets, moons, and extraterrestrial soil-containing bodies. This careful analysis allows astronomers to make comparisons from everything from the origin of our planet, early activity that may or may not have affected our planet or solar system, and possible catastrophes that may occur in the future. The students are presented with a soil sample from a few samples held by the instructor. These samples are collected or manufactured such that the gravel-sand-clay contents are significantly different and asked to categorize them. Students learn basics of soil testing as they perform the sieve analysis, moisture content, and shrinkage. These are done with screens purchased locally (screen door material, wire gauze, kitchen sieves) and made by the students of their own design or standard sieves. Moisture content and shrinkage are done with foil boats or molds, triple beam balance, and a low-temperature (100°C) oven (note*: if oven is not available, the samples can be placed in a hot, dry place outside for several days, perhaps over a weekend or in a fume hood under a “shop light” with a bright bulb).
Students compare data and determine common soil groups among the samples, and revise their earlier classification method of soils. The students are asked to then brainstorm a realistic method for performing these tests remotely.

**Engineering Connection**

Soils are important concern for civil engineers, as any soil-supported structure will have amounts of compression and heave that will affect the structure for years. Engineers test the soil before any construction in order to prevent any damage to buildings as the soils deform.

This translates directly to astronomy, as one of the most important pieces of information we can have about a body other than the Earth is a characterisation of its soils. These tests are not difficult to perform on Earth, but remote testing and collection is more difficult.

**Engineering Category**

*(Civil Engineering – Soil Mechanics)*

**Keywords:**

*Astronomy, Soil, Earth, Comparative Planetology, Soil Testing*

**Educational Standards:**

**TEKS 112.33 Astronomy**

(1) Scientific processes. The student, for at least 40% of instructional time, conducts laboratory and field investigations using safe, environmentally appropriate, and ethical practices. The student is expected to:

(A) demonstrate safe practices during laboratory and field investigations; and

(B) demonstrate an understanding of [make wise choices in] the use and conservation of resources and the proper disposal or recycling of materials.

(2) Scientific processes. The student uses scientific methods during laboratory and field investigations. The student is expected to:

(A) know the definition of science and understand that it has limitations, as specified in subsection (b)(2) of this section;

(B) know that scientific hypotheses are tentative and testable statements that must be capable of being supported or not supported by observational evidence. Hypotheses of durable explanatory power which have been tested over a wide variety of conditions are incorporated into theories;

(C) know that scientific theories are based on natural and physical phenomena and are capable of being tested by multiple independent researchers. Unlike hypotheses, scientific theories are well-established and highly-reliable explanations, but may be subject to change as new areas of science and new technologies are developed;

(D) distinguish between scientific hypotheses and scientific theories;
(E) plan and implement investigative procedures, including making observations, asking questions, formulating testable hypotheses, and selecting equipment and technology;

(F) collect data and make measurements with accuracy and precision;

(G) organize, analyze, evaluate, make inferences, and predict trends from data, including making new revised hypotheses when appropriate;

(H) communicate valid conclusions in writing, oral presentations, and through collaborative projects;

(3) Scientific processes. The student uses critical thinking, scientific reasoning, and problem solving to make informed decisions within and outside the classroom. The student is expected to:

(A) in all fields of science, analyze, evaluate, and critique scientific explanations by using empirical evidence, logical reasoning, and experimental and observational testing, including examining all sides of scientific evidence of those scientific explanations, so as to encourage critical thinking by the student;

(D) evaluate the impact of research on scientific thought, society, and the environment; and

(E) describe the connection between astronomy and future careers.

Pre-Requisite Knowledge

The student is familiar with laboratory procedures, and in writing laboratory reports.

Learning Objectives

After this lesson, students should be able to:

- Explain some of the important characteristics of soils.
- Conduct tests on soils for various properties.
- Organize and compare soil samples, and determine their relative origin.
- Suggest a method for extraterrestrial geological testing, and determine which tests are feasible.

Introduction / Motivation

Students are shown the objectives. As class begins, students are asked to create a chart in their notes to classify soils.

Students are led in a short discussion on their choice of characteristics and the tools needed to do this test.

Lesson Background & Concepts for Teachers

Soil analysis is an important facet of space and extraterrestrial exploration. When a soil sample is analyzed, much can be deduced from similarities and differences in soil structure and properties. An example of particular interest is the similarities in soil samples of lunar regolith to Earth soil.

Soils are created from the erosion of rocks (igneous, metamorphic, and sedimentary) by water or air flowing over them, or other chemical and physical weathering processes. Soil is composed of gravels, sands, silts and clays. These are categorized by particle size, with gravels being larger than 4.75 mm and clays being microscopic flake-like structures (0.002 mm). Soils also contain voids, or empty spaces, that can be filled with air or water. If air is present, the soil may be
compacted when a load (force) is applied on it and the soil will compress as the air is expelled and may expand if the load is moved off of the soil. If water is present, the water can be squeezed out, and will not expand unless more water is allowed to move in. Water is bound by chemical processes in between the sheets of clay, so a soil high in montmorillonite clay mineral can be “expansive” as the water physically forces the sheets of clay farther apart. This leads to many engineering challenges before building on a site can be attempted.

Basic tests are performed on soil to determine its composition, the amount of moisture in the soil normally, and its ability to hold water. The liquid limit and plastic limit of the soil are the amounts of moisture present in the soil when it performs like a limit, or a plastic respectively. Together with the shrinkage limit (the amount the soil shrinks in volume as water is driven off of it) these tests are called the Atterberg limits, and are the primary steps to classify soils in a manner that other engineers can communicate easily: for instance, an engineer that is told a soil at a site is classified as CL knows basic information about that soils behavior and can then order more specific tests based on his or her planned usage.

**Associated Activities**

Students construct a series of sieves, using materials such as screen material, wire gauze, and kitchen sieves. If these are not available, students may develop them from foil or cardstock and pencils, poking smaller and smaller holes or apertures in the cardstock to make small filters. Stick-pens may be used for the smallest holes. Students then sieve their sample (samples are given to each student/group by the teacher, and are massed by the students). Students perform a sieve analysis on the soil, and calculate the percent finer. Teachers may require the students graph % finer vs. particle size, if aperture size is known. Students record data of all the class for later comparison.

Students Perform a moisture test by creating a foil weighing boat, massing the wet sample, and drying it in an oven at approximately 100°C overnight. If an oven isn’t available, samples can be placed under a bright lamp or in direct sunlight for a few days or burn on a hot plate stove.

A shrinkage test is performed by slowly adding water to the sample until it is very wet and has a lowered viscosity, then poured into a boat or a mold (massing the sample) of known volume. After the water is dried, moisture content of the sample is calculated and the amount of shrinkage is measured.

Students are asked to determine, after sharing all their data, which samples are from the same or similar regions.

Students are asked to revisit their earlier categorization of soils.

**Lesson Closure**

A discussion of the difficulty in performing these tests remotely is prudent. Students are directed to write a laboratory report, and are informed that the next class will involve their planning a method to perform these tests at a remote location.

**Assessment**

Students are directed to write a formal report along class guidelines. Students are given immediate feedback as they discuss the categorization of the soils.
Lesson Extension Activities

Ask students to design a robot that can perform these tests on Mars. Alternatively, a discussion on having a robot do these tests on location vs. returning samples can be done.

References
Principles of Geotechnical Engineering, 3rd Ed., by Braja M. Das

Attachments
PowerPoint of lesson (coming soon)

Other
Culturally relevant/ethical connection: As writing prompt following this activity, these style questions are appropriate:

- You are a scientist that tests extraterrestrial soil, and make a discovery of great importance. You have an opportunity to contact the media (ensuring global communication of the find) or the government (ensuring your position as lead scientist and American possession of any data). What do you choose to do?

- A builder may choose to build without a soil test, running the risk that the home may be damaged at some point in the future but offering the home at a substantially cheaper price. If you were a builder, would you perform soil tests (and why or why not)?

- While doing a test on a rare sample of Martian Soil, you accidentally make a mistake that leads scientists to believe there is high moisture content in soils on Mars. No one suspects your mistake, and reports of this have led to unprecedented peace as everyone ponders the implications. It will be at least 20 years before another sample can be retrieved. Do you report your mistake?

- You did research long ago on a site a builder is using to build low-income housing, without a proper soil analysis. You tell the builder about a serious problem that may or may not cause damage to the housing, but the builder tells you he will not be able to build the units as low-income if you take your concerns public. What do you do? How would your answer change if the low-income housing was near a medium-to-high income neighborhood, and the builder has faced opposition to his plans?

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