Planetary Puzzles and Seismic Solutions

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Purpose

Middle school earth science curricula usually include a few lessons about the basic structure of the Earth. Students typically learn that the Earth has a crust, a mantle, and a core, and that the core is divided into a solid inner core and a liquid outer core. Our lesson plan assumes that the students have already learned this basic information. We take a step back and ask students to consider how we know anything about the Earth's interior. Our activity is designed to lead students through the same steps that seismologists used to discover Earth's liquid outer core. In doing so, they learn about P and S waves and discover the structure of a mystery planet.

Overview

We begin by asking students to brainstorm and discuss various methods that might be used for studying the Earth's interior. During this discussion, we introduce the idea of using seismic waves to study Earth's structure. Next, volunteers demonstrate how seismic (specifically P and S) waves propagate through solids and liquids. The class derives simple "rules" for the behavior of P and S waves in solids and liquids. Each student applies these rules to draw P and S wave paths through a planet of their own design. Finally, students trade P and S wave data with a partner and try to reconstruct their partner's planet based on P and S wave data alone.

Student Outcomes

Objectives

- Students will be able to (SWBAT) simulate and describe the behavior of P and S waves through solids and liquids.
- SWBAT draw simple P and S wave paths through a planet's interior, given its structure.
- SWBAT propose a structure for a planet, given a set of P and S wave paths.
- Students will describe and defend their proposed interpretation of the P and S wave data.

Illinois State Science Standards

- 12.C.3b Model and describe the chemical and physical characteristics of matter (e.g. atoms, molecules, elements, compounds, mixtures).
- 11.A.3f Interpret and present results of analysis to produce findings.
- 11.A.3g Report and display the process and results of a scientific investigation.

Time

This activity required one 80-minute period. This included enough time to have a few students share their interpretation and results with the class. We recommend leaving enough time for sharing examples because it had a positive influence on the quality of the lab writeups.

The lesson could be split up over two shorter periods. Two possible break points, depending on the ability and speed of the class, occur (1) after the students have finished drawing their planets but before drawing any paths or (2) after drawing P and S wave paths through their planet but before trading tracing paper.

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before drawing any paths or (2) after drawing P and S wave paths through their planet but before trading tracing paper.

Level

This lesson was taught in a 6th grade class whose curriculum covers general physical science, beginning with the metric system and moving through atmospheric and earth sciences and astronomy.

Materials and Tools

Required for each student:

- 1 "Original" template
- 1 "Proposed" template
- Half a sheet of tracing paper
- Ruler (for drawing straight lines)
- 2 colored pencils (different colors)

Optional but helpful:

- PowerPoint or smartboard to show example P and S wave paths
- Document camera for sharing students' results with the class

List of Supporting Materials

Filename	Description
seismic-wave-demo.pdf	Instructions for P and S wave demonstration. Thanks to Prof. Larry Braile at Purdue University for this great demo!
examplepaths.ppt	PowerPoint demo on drawing P and S wave paths. Also shows how to infer structure from P and S waves.
original-structure-template.pdf	Blank template for drawing original planet.
proposed-structure-template.pdf	Blank template for drawing proposed planet.
instructions.pdf	Written instructions for students. (We wrote, but didn't use these. Verbal instructions seem to work fine.)

Preparation

We suggest showing how to draw P and S waves through a sample planet in front of the class. A sample PowerPoint is included (examplepaths.ppt), or you can prepare your own example. When we taught this lesson, we used a smartboard to draw P and S wave paths through a simple two-layer planet.

Prerequisites

Students should be familiar with the basic compositional layers of the Earth: crust, mantle, outer core, and inner core. Some knowledge of P and S waves or earthquakes is helpful but not required.

Background

General content knowledge and skills students will need to succeed in this lesson. This should be written as if you are speaking to the students.

A few lessons ago, you learned about the structure of the earth. You learned it has a crust, mantle, and a core. You learned that the outer core is liquid and the inner core is solid. But how do we know any of that? We can't drill that deep—we can't even drill all the way through the crust! Even so, we're still pretty confident that we know the structure of the Earth's interior. Today you're going to follow the same steps that scientists used to discover the structure of the Earth—and that you might use in the future to study other planets.

Teaching Notes

This lesson plan is divided into five different sections.

1. Brainstorm and discuss: Ask the students how they think we could study the Earth's structure. Student ideas such as using radio waves or x-rays can lead into the introduction of seismic waves.
2. Introduce seismic waves: P and S waves are created by an earthquake and travel through the earth's interior. Demonstrate P and S wave motion using volunteers (see seismic-wave-demo.pdf). Have the students write down 4 questions and answer them:
    a. Do P waves travel in a solid? (yes)
    b. Do P waves travel in a liquid? (yes)
    c. Do S waves travel in a solid? (yes)
    d. Do S waves travel in a liquid? (no)
3. Generate P and S wave data:
    a. Students draw their own planet on the "Original" template, using different colors for solid and liquid layers.
    b. Students place their tracing paper over the original and trace its outline.
    c. On the tracing paper, students draw 5 seismic stations (seismometers) on the planet's surface and one earthquake somewhere in the planet's interior. Each station should be numbered for reference.
    d. Following the 4 "rules" derived from the demonstration, students draw P and S wave paths from the earthquake to each station on the tracing paper. Write a P next to each station that records a P wave and an S next to each station that records an S wave.
    e. If a student finishes early, they may draw an additional earthquake somewhere in the planet to give their partner more data.
4. Discover a "mystery" planet's structure:
    a. Students trade tracing paper with a partner. They should NOT look at their partner's original structure.
    b. Each student lays the tracing paper over the "Proposed" template. Using the 4 rules of P and S wave behavior, they try to draw their partner's planet.
5. Write up results (See the second part of the Assessment, below).

Assessment

We assessed the learning objectives in two ways.

First, we had a few pairs share their proposed structures with the class. Using the document camera, one partner showed and described their proposed structure. Next, they laid the tracing paper over the proposed structure and explained their reasoning based on the P and S wave data. Then their partner revealed the original structure. As a class, we compared the original and proposed structures. We discussed why or why not the original and proposed structures were different, based on the P and S wave data.

Second, we had each student write a short paragraph describing and defending their proposed structure. Because these 6th graders are just learning to write scientifically, we provided two "sentence starters": "I propose that the structure of my partner's mystery planet is…" and "The P and S wave evidence that supports this conclusion is…" Students were expected to describe their proposed planet's layers and identify a few P and/or S wave paths that were most helpful. If time allowed, we had a few students share these paragraphs with the class.