Hot Models: Evidence of Earth's Heat Distribution

Unit	Utah SEEd Standard / NGSS Performance Expectation	Estimated Lesson Time:
E.S.S. 2.2	Develop and use a model based on evidence of Earth's interior and describe the cycling of matter by thermal convection. Emphasize the density of Earth's layers and mantle convection driven by radioactive decay and heat from Earth's early formation. Examples of evidence could include maps of Earth's three-dimensional structure obtained from seismic waves or records of the rate of change of Earth's magnetic field. (PS1.C, ESS2.A, ESS2.B)	65 minutes

[Access lesson materials here.]

Lesson Overview

Learning Objective(s)

Students will learn about the heat under the Earth's surface and what processes are happening (cycling of matter by thermal convection) that can further provide evidence of Earth's formation and how mantle convection is driven by radioactive decay and heat. Students will use this evidence to develop and use several models of the Earth's interior.

Anchor Phenomenon

The phenomenon is a graph of pressure and temperature with the depth of the Earth. The phenomenon provides an inquiry into how scientists obtain evidence of temperatures within the Earth. Students will review how accretion, differentiation, and radioactive decay have generated heat within the Earth's interior since the formation of the Earth. Students will then understand processes such as boreholes, thermal convection, and S and P waves, which provide evidence of the physical properties of the Earth's layers.

Driving Question(s)

What evidence do we have of the temperature and materials of the Earth's interior the closer you get to the core?

Lesson Level Performance Expectations

Students will develop and use several models (temperature graph, S and P waves, and convection currents) based on evidence of Earth's interior and describe the cycling of energy and matter by thermal convection. Emphasize the density of Earth's layers and mantle convection driven by radioactive decay and heat from Earth's early formation. Examples of evidence could include diagrams of Earth's three-dimensional structure obtained from seismic waves or records of

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the rate of change of Earth's magnetic field. A student handout will be given to students to direct them to models relevant to the lesson intentions and provide several ways to model the introduced evidence found in the Earth's interior.

Lesson Snapshot

Lesson Summary:

	Estimated Time	Section Overview	How are students answering the driving question or meeting the learning objectives? (Highlight **SEPs**, **DCIs**, and **CCCs**)
Experience the Phenomenon	**20 minutes**	Students model radioactive decay and explain the sources of Earth's internal heat. They also watch a short video on the Kola super deep borehole and model how boring it into the earth gave us an understanding of temperatures within the earth.	Students model radioactive decay and explain the sources of Earth's internal heat. They also watch a short video on the Kola super deep borehole and model how boring into the earth gives us an understanding of temperatures (energy) and matter within the earth.
Investigate the Phenomenon	**30 minutes**	Students will conduct a lab experiment to understand thermal convection and then develop a model to show an understanding of the concept.	Students will conduct a lab experiment to understand thermal convection and develop a model to show an understanding of how temperature (energy) affects matter within the Earth to generate convection currents.
Model the Phenomenon	**15 minutes**	Students will review the concept of S and P Waves and utilize the idea to label charts of alien planets with layers according to the S and P waves native to those "new planets."	Students will use a model of S and P Waves to label model charts of alien planets with layers according to the S and P waves native to those "new planets." They will explain how the energy from an earthquake interacts with matter within the earth.

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Disciplinary Core Ideas	Science & Engineering Practices	Crosscutting Concepts
NGSS Appendix E (ESS2.A and ESS2.B) Deep probes and seismic waves, reconstruction of the historical changes in Earth's surface and its magnetic field, and understanding of physical and chemical processes that lead to a model of the Earth with a hot but solid inner core, liquid outer core, and a solid mantle and crust. Radioactive decay of unstable isotopes generates new energy driving mantle convection currents as a primary cause of plate tectonics.	**NGSS Appendix F** (Develop and use a model) Develop and use a model to describe the cycling of matter within the Earth. Use multiple types of models to provide mechanisms of the Earth's interior. Develop models that use data to identify transitions in layers within the Earth.	**NGSS Appendix G** (Matter and Energy) Matter and Energy: Energy drives the movement of matter through the Earth's geosphere via thermal convection, density, and gravity.

Materials

Student Materials	Teacher Materials	Lab Materials/Other Resources
Student worksheet SPED Student worksheet If you prefer students to work form composition notebooks you can use this worksheet. Optional extension article: The Deepest Hole	Lesson Slides Optional video explaining S and P waves Kosmo Video	Beakers Ice Food Coloring – red and blue Pipettes Heat source (Hot Plate/Microwave)

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Lesson Preparation

Material Preparation: Heated Water, Colored Ice Cubes/Ice Pops, Copies of the Student Handout

Required Previous Knowledge:

- S and P Waves (If students need to review or do not have this yet, show this video: **https://www.youtube.com/watch?v=huiiEehjUds)**
- Radioactive Decay
- Accretion
- Differential sorting
- Friction (from convection/differential sorting)
- Earth's Composition

Vocabulary Definitions:

- **Convection:** The heat transfer process from one region to another due to the movement of liquids or gases, like water or air. The initial heat transfer occurs through conduction, but the primary transfer occurs through convection. It is the dominant form of heat transfer in liquids and gases.
- **Accretion:** The process of gradual increase or growth, especially by additions from the outside.
- **Differential Sorting:** The sorting of materials on the Earth caused by movements from currents and convection.

Experience the Phenomenon/Problem (Engage)

What Students Are Doing	Teacher Tips
– Students will watch the video about the borehole and then use the information to fill out the data graph on the student handout. – Students will answer the prompt on the handout: (What do you notice or observe with the graph? What are you wondering about?) – After reviewing the three central claims of why it is hot inside the Earth (accretion, differentiation, and radioactive decay), students will list 2 of the main reasons why it is hot inside the Earth's interior. – Students create a model of radioactive decay with a radioactive atom.	Use the PowerPoint information to remind the students how the earth was formed and some of the resources and elements left during its formation. Explain to the students the central three scientific claims of why the Earth's interior is hot. Begin the evidence collection with Evidence #1
What Teachers Are Doing	**Teacher Tips**
– (Slides 1-8) – Introduce the phenomenon to the students in the PowerPoint and have them fill out the information on page one of the student handout.	Kosmo Video 6:05 – 6:50 (If cross-curricular information is desired watch the whole video (social studies/history)

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– Introduce students to the driving question (Why is the Earth's interior hot?) Students will list two of the three main reasons to provide a claim. – Provide Evidence #1 – Kola Borehole (Engage) – Show the following video about the Kola Bore Hole - Kosmo Video (show 6:05 – 6:50)	See sections for possible extensions for a link to the BBC article "The Deepest Hole We Have Ever Dug." Teachers, please allow students time to model on their worksheets before showing examples of models to avoid students copying from the slides.

INVESTIGATE THE PHENOMENON (EXPLORE)

What Students Are Doing	Teacher Tips

– Students will conduct a lab experiment to understand thermal convection and then develop a model to show an understanding of the concept.
– Students will follow the steps on their worksheet under the "explain" section. They should use hot water (colored red), cold water (colored blue), and room temperature water (no coloring added) to model convection currents.
– Students will use a pipette to carefully add hot water at the top and bottom of the room-temperature water.
– Students will place colored ice into the other beaker of room-temperature water.
– Once the students are done, they will use whiteboards and expo markers to model what they observed visually.
    ○ Make sure to add labels, movement arrows, etc.
    ○ Emphasize Matter and Energy in the model.
– Then, the students will walk through the gallery to observe how other groups modeled the convection currents.
– They will then come back and modify their own model on their whiteboard.
– Finally, under the direction of the teacher, the students will add a finalized model to their worksheet under the "explore" section.	

What Teachers Are Doing	**Teacher Tips**
– The teacher should use slides 13 – 16 to introduce convection currents to the students. Leave slide 16 projected so students can see the instructions in multiple places if needed. – Allow students to follow the steps on their worksheet to complete the explore portion of their worksheet.	The teacher can have the students develop a completed model as described in the lesson

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– Walk around the room to ensure that the students are handling lab equipment appropriately and are following lab procedures listed in the explore section of the student's worksheet. Check that students are highlighting matter and energy in their models. – Pass out whiteboards to each group and instruct the students to make a preliminary model of a convection current. – Once students have completed a model, they will nominate one student to stay with their model and explain it to others. The other students in the group should then complete a gallery walk of at least two other models. – Direct the students to make any final revisions to their model on their whiteboard, then have them copy their completed model to their lab worksheets. – The teacher will then use slides 17-21 to model convection currents further.	plan, or they can add a final step and have the class create a model together using components of their preliminary models.

MODEL THE PHENOMENON (EXPLAIN)

What Students Are Doing

- Students will review the concept of S and P Waves and utilize the idea to label charts of alien planets with layers according to the S and P waves native to those "new planets."
- Students will see several S and P graphs showing where each layer's transition occurs as it moves through different substances.
- Students will use the S and P graphs given in the worksheet to construct a model of the earth's interior.
- Next, students will recall their three main pieces of evidence from this lesson and list them in their worksheets.
- Students will add convection currents to their model's mantle and the layers' relative temperature.

Lastly, they will look at a "New World" model and use the S and P wave graph to create layers for a new planet.

What Teachers Are Doing

- Teachers re-teach the S and P graph and show the clear transitions from layers (Slide 24) to states of matter (Slide 25), to temperature (Slide 27), to a model of the earth split into a portion (Slide 28-29). This will help students develop their model in their worksheet.
- The answer key to the model for the earth is Slide 30. After students develop their model, they will review the three different evidences for the lesson (Slides 32-34). Once they have their three pieces of evidence, have them return to their S and P graphs and add **convection currents** and **temperature** information to the model.
- Instruct the students to complete the last section of their worksheet by creating the layers for their New World from a given S and P graph. (Slides 37-40)

POSSIBLE EXTENSIONS/ALTERNATIVE ADAPTATIONS

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BBC article: The Deepest Hole We Have Ever Dug

For SPED students, use this version of the worksheet

This lesson was created by Jake Morgan, Jamie Carling, and Mike Sanderson.

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