

Earth's Interior: What Lies Beneath?

<p>Unit Strand 2: Patterns in Earth's History and Processes</p>	<p>Utah SEEd Standard / NGSS Performance Expectation Standard ESS.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)</p>	<p>Estimated Lesson Time: 1-2 Class periods</p>
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LESSON OVERVIEW

Learning Objective

Students can develop and use a **model** of Earth's interior based on evidence to explain how variations in density and heat from radioactive decay drive thermal convection, which moves **matter and energy** beneath Earth's crust and causes geological activity.

- Density evidence → explain layering
- Convection evidence → explains movement of matter and energy
- Seismic waves → indirect evidence of internal structure
- Final model → synthesis of all three lines of evidence

Anchor Phenomenon

Image of the deepest holes in Earth's crust. If we haven't drilled through the crust, how do we know what it is like?

Driving Question

How can we find out what's happening beneath Earth's crust?

Lesson Level Performance Expectations

Developing and using models to show that **matter & energy** can be used to explain how **evidence from seismic waves reveals that Earth's interior is divided into layers of different composition and density, and thermal convection in the mantle is driven by radioactive decay and residual heat, causing the cycling of matter within Earth.**

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	10 min.	Students examine an image of the deepest drilled holes on Earth and discuss their ideas about how scientists collect evidence about Earth's interior, even without direct access to most of it.	Students start to think about their model of Earth's interior and how matter and energy flow through it via thermal convection and density.
Investigate the Phenomenon	40 min.	Students will move between stations to investigate density, convection, and waves.	At the lab stations, students collect evidence to help answer the driving question: "If we've never been inside the Earth, how do we know what's happening beneath our feet?" They observe how density affects layering, model thermal convection in the mantle using heated water, and analyze how seismic waves travel through different layers. Students then use this evidence to develop and revise models of Earth's interior, showing how energy and matter interact within Earth as part of a larger system. These activities help students meet the learning objective by explaining how Earth's internal processes work, even without direct observation.
Model the Phenomenon	20 min.	Students will revise their initial models of Earth's interior to incorporate how differences in density, thermal convection, and seismic wave behavior provide evidence for Earth's layered structure and internal processes.	As students revise their initial Earth-interior models, they weave in three lines of evidence: density differences, thermal convection, and seismic-wave patterns . They are using the SEP Developing and Using Models to update drawings with layers, convection arrows, and wave paths. By doing so, they connect how energy and matter cycle within a complex system and demonstrate, in a single coherent model, how indirect evidence reveals Earth's layered structure and internal processes.

DISCIPLINARY CORE IDEAS	SCIENCE & ENGINEERING PRACTICES	CROSSCUTTING CONCEPTS
<p>NGSS Appendix E Radioactive decay within Earth's interior contributes to thermal convection in the mantle.</p>	<p>NGSS Appendix F Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.</p>	<p>NGSS Appendix G Students learn that the total amount of energy and matter in closed systems is conserved. They can describe changes in energy and matter in a system in terms of energy and matter flows into, out of, and within that system. They also learn that energy cannot be created or destroyed. It only moves between one place and another place, between objects and/or fields, or between systems. Energy drives the cycling of matter within and between systems. In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.</p>



Related knowledge and skills from prior grades

<p>Disciplinary Core Idea: NGSS Appendix E</p> <p>Energy flows and matter cycles within and among Earth's systems, including the sun and Earth's interior as primary energy sources. Plate tectonics is one result of these processes.</p>	<p>Science and Engineering Practices NGSS Appendix F</p> <p>Develop a model to describe unobservable mechanisms.</p>	<p>Crosscutting Concept: NGSS Appendix G</p> <p>Students learn that matter is conserved because atoms are conserved in physical and chemical processes. They also learn within a natural or designed system; the transfer of energy drives the motion and/or cycling of matter. Energy may take different forms (e.g., energy in fields, thermal energy, energy of motion). The transfer of energy can be tracked as energy flows through a designed or natural system.</p>
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Materials

Link to all materials on the 3DRST website (3drst.byu.edu): <https://3drst.byu.edu/ess-2-2-earth-interior>

Link to all materials on Canvas Commons: <https://3drst.byu.edu/ess-2-2-earth-interior>

Student Materials	Teacher Materials	Lab Materials/Other Resources
<ul style="list-style-type: none"> - Student Handout - Student Handout (accommodation version) - Convection Articles - Modeling Rubric - Modeling Rubric Scoring Sheet - Pencil/Pen - Device to access the internet 	<ul style="list-style-type: none"> - Station Instructions - Station Information Sheets - "What Lies Beneath" slides with Teacher notes in the lower margin 	<p>DEMO 1: Density tank or clear container; petroleum jelly to seal the tank; hot and cold water; food coloring.</p> <p>Station 1: liquids (corn syrup/honey/molasses; dish soap; water; oil); 100 mL graduated cylinder; food coloring (optional)</p> <p>Station 2: Density cubes (2 sets), Digital Scale (2)</p> <p>Station 3: Lava lamp</p> <p>DEMO 2: Wave generators (long spring/slinky, heavy rope, telephone cord) of approximately the same length</p> <p>Station 4: Seismic Wave Simulation</p> <p>https://tinyurl.com/ymy928dh https://youtu.be/hyoLYPvvA3o</p>

LESSON PREPARATION

Material Preparation:

It is extremely important for the teacher to have all lesson materials prior to this lesson.

Print the student worksheets, the lab station instruction sheets, and the articles.

Convection Current Station: 2 lava lamps turned on early enough for the wax to start circulating.

This corresponds to the student worksheet.



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Teacher Demonstration 1 – Density Tank Observations: You will need a density tank with a center divider, ice water in a blue beaker, and hot water in a red beaker. If you do not have a density tank, you can use a clear 5- or 10-gallon container and two test tubes: one containing hot red water and the other containing cold blue water. ([Density Box Demonstration](#))

Station 1 - Liquid layering : You will need large test tubes or 100 ml graduated cylinders, enough of the following liquids: Corn syrup or molasses, an oil of your choice (we used corn oil), dish soap (colored, we used Dawn), water, and food coloring to color the water (we used red), as spoon to pour the liquids over into the test tub or graduated cylinder, separate beakers or graduated cylinders for different amounts of the liquids.

Station 2 - Density Cubes: Set or sets of density cubes, a digital scale, and metric rules to measure the cubes.

Station 3 – Lava Lamp: Plug it in as early as possible to ensure it works. Students will observe the lava lamp while it is in motion

Teacher Demonstration 2 - Seismic Waves: You will need a 10 ft piece of nylon rope ($\frac{1}{2}$ " or $\frac{5}{8}$ "), a long, coiled telephone cord, and a long spring (a metal slinky will work).

Station 4 – Seismic Simulation: Run the simulation and have students observe what happens. You may need to run the simulation multiple times and explain what is happening. One idea is to run it for observation only, then run it again and identify what is happening at each stage.

Required Previous Knowledge:

This lesson builds on students' prior understanding of the following disciplinary core ideas (DCIs) developed in previous units:

- ESS2.A: Earth's Materials and Systems – Students should understand that planets, including Earth and Mars, are made of layers (crust, mantle, core) with distinct properties and compositions.
- PS4.A: Wave Properties – Students should know that waves travel at different speeds through solid and liquid materials
- PS3.B: Conservation of Energy and Energy Transfer – Students should know that heat transfer occurs via convection within planetary mantles and that this affects geologic processes.
- PS1.A: Structure and Properties of Matter – Students should recognize that differences in density can influence how energy and materials move within a planetary body.

Supports students will need/adaptations:

- There is an **accommodated version of the student worksheet** that includes sentence starters, vocabulary supports, and chunked modeling steps to assist language learners and developing writers. Please note that the stations are arranged slightly differently on this version.
- Visual aids such as diagrams, models, and animations will support understanding of waves, density, and convection.
- Scaffolded vocabulary and sentence starters will help all students construct explanations using key terms.
- Collaborative group roles and chunked instructions will promote engagement and make tasks more manageable.
- Supports for ELs and SPED students, including word banks, visuals, extra time, and multiple response formats.



- Flexible modeling options, allowing students to show understanding through drawings, physical models, or digital tools.

Vocabulary Definitions:

- **Seismic Waves** – Vibrations that travel through a planet, often produced by earthquakes, which help scientists learn about its internal structure.
- **S-Waves (Secondary Waves)** – A type of seismic wave that moves material side to side and cannot travel through liquids. They help identify where liquid layers exist inside a planet.
- **Convection** – The movement of heat through fluids (like molten rock or gases), where hotter, less dense material rises and cooler, denser material sinks.
- **Density** – The amount of mass in a given volume of a substance; in planetary science, it helps determine how materials layer within a planet.
- **Model** – A representation (such as a drawing, diagram, or physical object) used to explain or predict something that cannot be directly observed.
- **Crust** – The outermost layer of a planet, typically solid and relatively thin compared to deeper layers.
- **Mantle** – The thick, mostly solid layer between the crust and the core, where convection often occurs.
- **Core** – The central part of a planet, often divided into a solid inner core and a liquid outer core, depending on the planet.
- **Wave Properties** – Characteristics of waves, including speed, wavelength, and amplitude, that affect how they move through different materials.
- **Indirect Evidence** – Information gathered from observations or models (like seismic waves) that help scientists infer things they can't directly see or touch.

EXPERIENCE THE PHENOMENON/PROBLEM (ENGAGE)

What Students Are Doing	Teacher Tips
<ul style="list-style-type: none"> - Students will observe the image on slide two showing holes drilled into Earth's crust and complete the See, Think, Wonder section of their assignment. They will then view slide 3, which shows Earth's interior, and add to their responses. - Students participate in a class discussion about previous knowledge of Earth's interior and work together to identify the names of the layers. - As a class, they will discuss prior knowledge about Earth's interior and create an initial model to show their understanding. - Students will then partner up to discuss key facts from the video and/or their initial model 	<ol style="list-style-type: none"> 1. Model See, Think, Wonder Before students start, demonstrate how to fill out each column with a simple example to help guide their thinking. 2. Encourage Curiosity Promote open-ended questions in the "Wonder" section to spark curiosity and foster deeper discussion. 3. Facilitate Class Discussion Use guiding questions to activate background knowledge and spark discussion: <ul style="list-style-type: none"> • "How do scientists know what's inside the Earth?" • "What evidence supports these models?" • "If we can't drill that far, how do we find out what's down there?" Chart responses on the board.

	<p>4. Monitor Partner Discussions Circulate the room to prompt deeper thinking and correct misconceptions during partner discussions.</p>
What Teachers Are Doing	Teacher Tips
The teacher will guide a class discussion using slides 2 and 3, encouraging students to share their observations and input. Then, the class will discuss prior knowledge of Earth’s interior, and the teacher will create a word bank on the board with the four layers: crust, mantle, outer core, and inner core.	Ensure that the question “how do we know what the Earth’s interior is like?” is asked. If necessary, provide the class with some hints to help them think about that.

INVESTIGATE THE PHENOMENON (EXPLORE)

What Students Are Doing	Teacher Tips
<ul style="list-style-type: none"> - Students will observe the density demonstration. - Students will split into groups and rotate through stations (lava lamp, liquid density, and cube density). - Students will watch the teacher’s wave demonstration. - Students will participate in the waves station. - Students will explore the seismic waves simulation and view a video on S-wave shadow zones. 	<p>Teacher Notes:</p> <p>Density Demo (Teacher-Led): Guide students to observe how materials layer based on density. Ask: <i>“What do you notice about the order?”</i></p> <p>Station Rotations: Divide students into small groups. Rotate through:</p> <ul style="list-style-type: none"> ○ Lava Lamp – Discuss convection and heat transfer. ○ Liquid Density – Observe how different liquids layer. ○ Cube Density – Use tools to calculate and compare densities. <p>Wave Demo (Teacher-Led): Use a spring to demonstrate P-waves (push) and S-waves (side-to-side). Ask guiding questions about speed and direction.</p> <p>Waves Station: Students use hands-on tools (rope/slinky) to recreate</p>

	<p>wave motion. Monitor for accuracy and encourage comparison to the demo.</p> <p>Seismic Simulation & Video: Students explore wave paths and shadow zones. Instruct them to observe how waves travel through different Earth layers and what these reveal.</p>
<p>What Teachers Are Doing</p>	<p>Teacher Tips</p>
<p>Remind students that each station provides evidence to help answer the driving question: “How can we find out what’s happening beneath Earth’s crust?”</p> <p><u>Teacher Demo 1: Density Tank</u></p> <ul style="list-style-type: none"> • Point out the visual and ask students what they notice about molecule placement. Connect this to energy and density. • Before the demo, have students predict where the hot (red) and cold (blue) water will go and why. • Demonstrate how hot and cold water interact using a density tank or a clear tank with pipettes. • Students record observations and answer analysis questions in the “Teacher Demo 1: Density Tank Observation” section of their worksheet, focusing on how heat affects density and movement of matter. Emphasize that students must connect their observations to how energy moves inside Earth. <p><u>Stations</u></p> <p>Station 1: Liquid Layering:</p> <ul style="list-style-type: none"> • Set up before class: Corn syrup, dish soap, water, oil, food coloring, beaker or graduated cylinder. • Students complete the “station 1: Liquid Layering” data table in their worksheet and identify which Earth layer each liquid represents. Students must answer how density determines position and how this explains Earth’s layered structure. <p>Station 2: Density Cubes: Density cubes, ruler, TBB or scale, calculators.</p> <ul style="list-style-type: none"> • Monitor students and ask questions to support critical thinking and discovery. <ul style="list-style-type: none"> ○ What pattern do you notice in how materials are arranged? ○ What does this suggest about Earth’s layers formed? 	<p>*** Make sure students are reading the articles and instructions as important information is included in those documents. ***</p> <p>Density Demo</p> <ul style="list-style-type: none"> • Have students predict where hot/cold water will go. • Point out molecule placement and relate to density. <p>Lava Lamp Station</p> <ul style="list-style-type: none"> • Preheat lamp at least 1 hour. • Use guiding questions about convection and heat. <p>Density Stations: Liquid layering and Density Cubes</p> <ul style="list-style-type: none"> • Ensure materials are ready and labeled. • Ask why liquids/cubes layer or differ in density. <p>Wave Demo</p> <ul style="list-style-type: none"> • Use slinky to show P-waves (push) and S-waves (side-to-side). • Ask which moves faster and why. <p>Wave Stations</p> <ul style="list-style-type: none"> • Provide instructions and simulation video.



- Students calculate density, compare to their heft ranking, and complete the “station 2: Density Cubes” table in the worksheet. Students answer how quantitative density data supports the same pattern observed in liquid layering.

Station 3: Lava lamp

- Set up the station in advance with the **Instruction Sheet** and **Background Info**.
- Ensure the **lava lamp is plugged in and preheated** (may take up to an hour).
- **Monitor students** and ask guiding questions to encourage thinking and discovery.
- Students record 2-3 observations in the “Lava Lamp Mini-Investigation” section of their worksheet and answer wrap-up questions connecting heat to convection and mantle movement.
- Prompt students to predict what would happen if Earth did not have an internal heat source.
- Ask: “Where does the heat that drives convection inside Earth come from?”

Teacher Demo 2: Seismic Waves

- Begin by asking students what they know about waves.
- Direct their attention to the screen, then move to a smooth surface (desk, floor, or hallway) for the demo.
- Have a student hold one end of the spring; the teacher holds the other end and generates the wave.
- **P-wave:** Push one end quickly to create a **back-and-forth (compressional)** motion. Ask: *Does it move fast or slow? Is there reflection?*
- **S-wave:** Move the spring side to side to show a transverse wave. Ask the same questions.

Station 4: Simulation – Interpreting a Seismic Wave

- Set up station with **Instruction Sheets** and **Background Info** before class.
- **Materials:** Rope, spring/slinky, telephone cord, smooth surface, timer.
- **Simulation:** Load video at tinyurl.com/ymy928dh on a computer. Present students with directions on the PPT slide
- Monitor student progress and ask guiding questions to support discovery.
 - Which wave disappears? Where? What does that suggest about that layer?
 - Have students look at one wave type at a time. Which one is moving faster? Slower? Which layers does each wave pass through? Are there any layers that a wave cannot go through? Why might this be?
- Students complete the “Generating seismic waves table” and “Simulation – Interpreting a Seismic Wave” Sections of their worksheet while observing demonstrations and simulations.

- Focus on wave speed, paths, and where waves stop.

Final Analysis

- Lead discussion on density, convection, and seismic waves.
- Show seismic video and have students revise models.



- Emphasize that students must identify what wave types pass through which layers and infer what this reveals about the state of matter inside the Earth.

Ask students to add at least one new piece of evidence from the stations to their Earth model before moving to the final model.

Final Analysis AND Wave Simulation

- Have students share key findings from the three stations.
- Guide discussion with questions such as:
 - *Which materials were most/least dense? How were they sorted?*
 - *How does density explain the layering of Earth?*
 - *How do convection currents move? Where do they occur in Earth's layers?*
 - *How do P- and S-waves move? How are they alike/different?*
 - *How do scientists use this evidence to understand Earth's interior?*
- Show a **short video on seismic waves**.
 - Instruct students to make **final observations** and use them to **revise their Earth model**.

MODEL THE PHENOMENON (EXPLAIN)

What Students Are Doing

- While exploring the stations and demos, students will build a revised model of Earth's interior, incorporating new information they have collected along the way. They should follow the checklist provided on the worksheet.
- Preferred: students receive a new paper to create a finalized version of their model. They initially made a model on page 1 of the worksheet and a revised model on the last page. Students revise their model to ensure that all aspects are clearly shown.
- Students will answer summary questions to show learning.

Teacher Tips

Emphasize Model Progression

Remind students that their final model should show growth from their initial version—highlighting new learning from each station.

Provide Clear Expectations

Review the **modeling checklist** before students begin. Consider displaying it on the board or projector to keep students focused.

Encourage Neat, Labeled Final Models

Provide clean paper for the revised model. Encourage students to use **color, labels, and structure** to clearly represent Earth's layers and key concepts (e.g., density, wave motion, convection).

Circulate and Confer

Walk around as students work to clarify misunderstandings, ask probing questions, and ensure they're incorporating evidence from each station.



<ul style="list-style-type: none"> - Students use the modeling checklist included in their worksheet to ensure their revised model incorporates evidence from all three investigations (density, convection, seismic waves). Their final model should reflect revisions made from their initial model and demonstrate how evidence supports Earth’s layered structure and internal energy transfer. - Students complete the Summary Questions section of the worksheet to construct an evidence-based explanation answering the driving question. - Students refer back to their worksheet responses from each station to identify at least three pieces of evidence that support their final model of Earth’s interior. 	<p>Frame the Summary Questions as Reflection Remind students the summary isn’t just a test—it’s a chance to explain what they’ve learned and how their thinking evolved.</p> <p>Offer Sentence Starters or Word Bank (if needed) Especially helpful for younger students or language learners when answering open-ended summary questions.</p> <p>A proficient model should include:</p> <ul style="list-style-type: none"> • Correctly ordered layers with relative thickness • Convection arrows in mantle with energy sources listed • P- and S-wave paths, including where S-waves stop • Labels referencing density differences
<p>What Teachers Are Doing</p>	<p>Teacher Tips</p>
<p>Teachers ensure that students follow the checklist and clarify any questions about how to illustrate a concept or about general aspects of their models.</p> <p>Return to the driving question, “How can we find out what’s happening beneath Earth’s crust?”</p> <ul style="list-style-type: none"> • Claim • Evidence • Reasoning <p>Formative Assessment:</p> <ul style="list-style-type: none"> • Station data tables • Lava lamp predictions • Wave interpretation responses <p>Summative Assessment</p> <ul style="list-style-type: none"> • Final revised model (scored using modeling rubric) • Written summary explanation answering the driving question. 	<p>Actively Reference the Checklist Remind students to use the checklist as a guide. Ask, “<i>What’s the next item you need to include?</i>” to keep them on track.</p> <p>Clarify Without Giving Answers When students ask how to draw or explain something, prompt them with:</p> <ul style="list-style-type: none"> - “<i>What did you observe at that station?</i>” - “<i>How could you represent that with arrows, labels, or layers?</i>” <p>Encourage Visual Simplicity Let students know their models don’t have to be artistic—clarity and accuracy are the goals. Suggest basic symbols or diagrams if needed.</p> <p>Look for Misconceptions As students work, watch for inaccurate representations and gently correct them by asking guiding questions.</p> <p>Support Thoughtful Revisions Reinforce that their final model should reflect new learning. Ask: “<i>What did you change from your first model, and why?</i>”</p> <p>Give Specific Feedback Instead of general praise, say things like:</p>



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| | <ul style="list-style-type: none">- "I like how you showed convection currents in the mantle."- "Consider adding wave direction arrows for P- and S-waves." |
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POSSIBLE EXTENSIONS/ALTERNATIVE ADAPTATIONS

Optional Challenge (Advanced Groups):

Try passing waves through different materials, such as holding one end through a desk leg or a thick object, and observe any changes. Relate this to seismic wave speeds in the crust, mantle, and core.

Reflection Questions:

- What evidence do scientists gather from seismic waves to understand Earth's layers?
- How does this model help you visualize wave behavior inside Earth?
- What are the limitations of using a slinky or rope to model real seismic waves?

Adaptations:

The final model can provide word banks and arrows/lines to help organize their model.

How do we know that the core is solid Nickel and Iron?

Dive into magnetic fields as evidence.

This lesson was created by Mary Lamoreaux, Parker Peterson, and Ken Thornock