

“Extending the CTE-STEM Pipeline into Middle Schools”

Green Engineering

Solutionary Phase	Problem Cycle 1
Lesson # and title	Lesson 5: Exploring Thermal Expansion
Duration	45 minutes

Lesson Overview

How do we know that global warming is contributing to the expansion of the oceans? During this lesson, students will engage with a NASA Jet Propulsion Lab activity “How warming water causes sea level rise” to witness the effects of increasing water temperature on its volume. Students will learn that the volume of water depends on its temperature, where warmer water takes up more space than cooler water due to the nature of bonding water molecules.

Learning Objectives

1. Climate change can be modeled.
2. Global warming is heating up the oceans, thereby expanding the volume of the oceans (sea level rise).
3. As sea levels rise, they impact coastal areas and the populations that live there.

Content Standard(s)

MS-ESS2-6: Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.

MS-PS1-4: Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.

College and Career Connection(s)

Oceanographer
Climate scientist
Cartographer

Equipment, Instructional Resources, and Materials

- Slide Deck:  Lesson 5: Exploring Sea-Level Rise
- Thermal Expansion Model (teacher version): <https://www.jpl.nasa.gov/edu/teach/activity/thermal-expansion-model/>
 - How warming water causes sea level rise (same project - student version): <https://www.jpl.nasa.gov/edu/learn/project/how-warming-water-causes-sea-level-rise/>
- Materials (per group):
 - Plastic water bottle with flip lid
 - Clear plastic straw
 - Food coloring
 - Ruler
 - Permanent marker
 - Cutting tool
 - Hot glue gun or puddy
 - Heat source
 - Safety Goggles (only if using an exacto knife or hair dryer)
- [Student worksheet](#) (skip if short on time)

Suggested Student Grouping

Small groups (2-3)

Vocabulary

Thermal expansion

The Lesson
[Link to Slide Deck](#)

Preparation

Prior to Class

- Prepare all materials. Students should work in groups of 2-3.
 - Print out or create digital copies of  Exploring Sea-Level Rise Student Worksheet (if using)
- Read/Watch Video for Thermal Expansion Model activity: <https://www.jpl.nasa.gov/edu/teach/activity/thermal-expansion-model/> and student version: <https://www.jpl.nasa.gov/edu/learn/project/how-warming-water-causes-sea-level-rise/>
- Different heat sources apply heat to the water with different intensities and larger quantities of water can absorb greater amounts of heat, meaning the time it takes to notice a change in temperature and water height may vary. Consider making and testing one of these models in advance to get an idea of how long it may take. This will help you to determine how long students should wait in between measurements. Record how long it takes for water to rise 0.5 to 1.0 cm and use that time as an approximate interval.

Lesson Procedure

Activity/Task	Description	Time (min)
Global temperature and Sea level Rise (slides 1-3)	1. Show students the “Global Temperature” and “Sea Level Rise” graphs on this site: https://www.jpl.nasa.gov/edu/teach/activity/thermal-expansion-model/ 2. Ask students, “Is there a relationship between the temperature of water and sea level rise?” 3. Tell students, “We’re going to do an activity to answer this question.”	3
Assign small groups and distribute materials	1. Create student groups of 2-3 (or create groups prior to class). 2. Review/demo lab safety 3. Distribute materials to each group.	5
Activity Instructions (slides 4-12)	Determine if you have time to do the full lab write-up. If so, pass out student worksheets. Have students read the question and write a hypothesis prior to starting the experiment. <u>Use these instructions</u> (video included) or follow the instructions below: 1. <u>Prepare the bottle:</u> a. Using the cutting tool, create a hole in the bottle cap large enough to insert a straw. (You can skip this step if using	30

	certain types of flip cap water bottle) b. Completely fill the bottle with water to the rim. You can use food coloring to make the water more visible. Colored water isn't required. 2. <u>Prepare the straw:</u> a. Insert the straw into the bottle cap, making sure to leave 2-3 inches (5-8 cm) above the cap. Seal the hole around the straw with clay or hot glue to ensure that neither air nor water can escape between the straw and bottle cap. b. Screw the cap onto the bottle. 3. Using the marker, draw the "zero line" of water on the straw. 4. Point the heat source directly at the bottle from a relatively close distance. 5. At regular intervals – every minute or five minutes – measure and record the water level in millimeters, starting from the zero-level mark drawn on the straw. Make note of what's happening. For each measurement, you should align the "0" mark on the ruler to the zero-level mark you made in Step 4. 6. Write a description of what you observed in the straw. Graph your measurements on paper or using spreadsheet software. (skip this step if short on time) a. Extension: have the students all add their data to a single spreadsheet and create a class graph. Discuss the trends and variability in the data. Discuss possible errors in the data and/or methods of the experience. Discuss why a bigger sample size and repeated experiments are important to have reliable results.	
Conclusion (slides 7-15)	● Ask students what happened to the water level as heat energy was added. ○ Based on their graph, have them write a conclusion answering the question above and discussing if their hypothesis was correct. Suggestion: Use a CER (claim, evidence, reasoning) format. (skip this if short on time) ○ Discuss with students: This activity demonstrated that the volume of water increases when its temperature increases (direct correlation). ● Show students the animation of thermal expansion. Discuss how the molecules in water start moving faster as they are heated up.	7

	This causes the molecules to spread out and the water to increase in volume. • Ask students, “How does this model help us understand what is happening in Tuvalu and other Pacific Island nations?” • Play short video clip on slide 15	
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Assessment/Extension

1. Slide 16: Engineering Design Notebook: Bonus/Extension - This can be assigned as a reflection (in-class or homework) or introduced at the beginning of the lesson for students to take notes in during the lesson. Students can be given the choice in how they would like to capture their notes/reflections such as pencil/paper, Google slides, or Book Creator.
 - a. [Sample Book creator link](#): (optional) - Suggestion: Have students choose which reflection questions they would like to answer.
2. Optional Assessment/Reflection: Ask students to identify causes of sea-level rise with sufficient detail to demonstrate understanding:
 - Melting ice is contributing to the rise of sea level. As land ice melts, it runs into the ocean and increases the amount of water in ocean basins. Sea-ice melt does not contribute to sea-level rise, as the melted ice fills the space previously occupied by the frozen sea ice.
 - The ocean’s heat capacity allows it to absorb a lot of energy in the form of heat as land and air temperatures rise. When water is warmed, it expands and takes up more space, a phenomenon known as thermal expansion. Thermal expansion increases the volume that ocean water takes up, leading to sea-level rise.
2. Optional Extension: Have students research the following careers: Oceanographer, Climate Scientist, Cartographer. Ask students to describe the careers, the different academic pathways required to enter that career, and what role they could play in Tuvalu in its efforts to combat or adapt to the impacts of climate change.
3. Optional Extension: Albedo Effect - [Video](#) (video can be heavy - recommend pairing with a [trauma informed practice](#)), [Interactive activity](#), [Article](#)