GREAT LAKES LEARNING

LESSONS & ACTIVITIES BASED ON THE MONTHLY GREAT LAKES NOW PROGRAM

EPISODE 2404 | WARMING WATERS AND MUTANT CRAYFISH

SUPERIOR WATERS WARMING

OVERVIEW

This lesson will explore the phenomenon of **warming waters** in Lake Superior, The coldest and largest of the Great Lakes has been experiencing steady increases in average temperatures for a few decades, enough to give rise to concern for the lake ecosystem, the weather patterns in the surrounding area, and more. But before solutions can be explored, we must first understand the problem. That's why, through hands-on experiments, students will explore thermal stratification, model algal blooms, and investigate the impact of ice coverage.

LESSON OBJECTIVES

- **Know** why the waters of Lake Superior are warming
- **Understand** how thermal stratification works in lakes
- **Be able to** model the albedo effect, thermal layering, and algal blooms with household materials

WHAT YOU'LL NEED

- Computer or mobile device with Internet access to view video and online resources
- Notebooks and pencils
- Chart paper
- Sticky notes
- Markers
- Lab supplies (see individual activities for a full list)
- Copies of the Student Handouts

INTRODUCTION

Historically known for its frigid waters, Lake Superior is the biggest of the five Great Lakes. But climate change has been gradually warming the lake, resulting in higher-than-ever temperatures, reduced ice and snow cover, and for the first time in recorded history algal blooms. In order to better understand the impact and significance of this phenomenon of the warming of the waters, an investigation of some of the underlying scientific principles is in order. While it may not be possible to take a trip to Lake Superior to test water conditions there directly, we can employ a technique that scientists commonly use—modeling—to explore this phenomenon and its implications on a smaller scale within the confines of the classroom and transfer our learning to the lake.

This lesson includes multiple activities, including lab activities, that can span the course of several sessions or be adapted to fit the needs of your group's meeting format.

Some prior knowledge* with which students should be familiar includes:

- energy storage and transfer
- properties of water
- density
- temperature and states of matter
- phase changes of matter

Follow this QR Code or hyperlink to the Episode Landing Page!

Check out our full collection of lessons for more activities related to topics like these.

****The sequence of these activities is flexible, and can be rearranged to fit your teaching needs.***

NGSS CONNECTIONS

Phenomenon: Warming Lake Waters

- MS-ESS2-1
- MS-ESS2-4
- MS-ESS3-1
- MS-ESS3-5
- MS-LS2-4
- SEP 2
- SEP 3
- SEP 4
- SEP 6

During the course of the lesson, students will progress through the following sequence** of activities:

- Class discussion to elicit and activate prior knowledge about **Lake Superior**
- Teacher notes on **warming waters and thermal stratification** in Lake Superior
- Watch a segment from *Great Lakes Now* about the warming waters of Lake Superior
- Class discussions to debrief the video
- Read about how some **National Parks are moving away from fossil fuels**
- Conduct an experiment to **model thermal stratification**
- Investigate how **algal blooms** occur
- Simulate the **albedo effect** on melting ice

The lesson progresses through three major sections: **launch, activities, and closure.** After the launch of the lesson, you are ready to begin the lesson activities. Once finished with the activities, students will synthesize their learning in the closure. You can select the activities that are best suited for your learners and teaching goals, and then sequence them in a way that makes sense within your learning progression and the scaffolds of the lesson.

If you use this lesson or any of its activities with your learners, we'd love to hear about it!

Contact us with any feedback or questions at:
GreatLakesNow@DPTV.org

TEACHER BACKGROUND INFORMATION

by Gary G. Abud, Jr., Great Lakes Now Contributor

**This information can be presented by the teacher as notes to students at the teacher's discretion.*

Lake Superior, the largest, deepest, and coldest of the Great Lakes, is undergoing significant changes due to rising global temperatures. Historically known for its frigid waters, Lake Superior is now warming at an alarming rate. This phenomenon has profound implications for the lake's ecosystem, local weather patterns, and the communities that depend on the lake for recreation, tourism, and business.

Lake Superior holds 10% of the world's surface freshwater, covering an area of more than 30,000 square miles and reaching about a quarter of a mile at its maximum depth. Its waters have traditionally stayed cold, even during summer months. This is partly due to the lake's depth and volume, but also because water has a high **specific heat capacity** of 4.18J/g˚C. This high specific heat means water can absorb or release a large amount of energy with only a small change in temperature. For example, to raise the temperature of 1g of water by 1˚C, it requires 4.18 joules of energy—about the energy needed to press the spacebar on a keyboard 1,000 times.

Energy transfer to the water can come from the sun's light or molecules in the air near the lake surface. As water molecules absorb energy, they move faster, raising the temperature of the water. This warming starts at the surface, with faster-moving molecules colliding with slower ones below, eventually transferring energy throughout the entire system and increasing overall lake temperatures.

Though Lake Superior's temperature changes throughout the year, its depth and volume prevent drastic fluctuations, keeping it generally cold compared to the other Great Lakes. However, rising global temperatures have begun to alter this long-standing characteristic. The layering of water at different depths due to temperature differences—known as **thermal stratification**—varies by season, but warmer overall waters reduce this variation. In summer, warmer, less dense water sits atop colder, denser water, affecting nutrient mixing and oxygen levels—both are crucial for aquatic life in Lake Superior.

Significant and well-documented warming trends began in the late 1900s, with global temperatures rising on average for over a century prior. Since the late 20th century, average global temperatures have increased, leading to widespread climate shifts. These changes are particularly evident in large bodies of water like Lake Superior. The lake's surface water temperatures have risen about 2.5˚C over the past 30 years, a rate faster than many other large lakes worldwide. This warming trend affects several aspects of the lake's environment and the broader regional climate. It's part of **climate change**, driven largely by human activities such as burning fossil fuels, deforestation, and industrial processes that increase greenhouse gas concentrations in the atmosphere.

Other factors influence the warming of Lake Superior's waters. The **albedo Effect** measures how much sunlight is reflected by a surface. Ice and snow have high albedo, reflecting most sunlight, while darker surfaces like water have low albedo and absorb more energy. Reduced ice and snow cover on Lake Superior lowers the albedo, leading to further warming, even in winter months. Additionally, because ice acts as an insulating layer, regulating water temperature, reduced ice cover compounds the temperature increases in Lake Superior.

These factors ultimately affect not just the waters themselves but every living organism that depends on them. The warming of Lake Superior is a clear indicator of the broader impacts of climate change on freshwater ecosystems like the Great Lakes.

Understanding these changes is crucial for scientific monitoring and developing strategies to mitigate and adapt to the evolving climate.

LESSON LAUNCH

A. Warm Up

The warm up is intended to be structured as teacher-facilitated, whole-group student discussion activities. It helps students to begin thinking about the topic at the center of the lesson.

1. Ask students to list out on a piece of paper five things that come to mind when thinking of **Lake Superior**.
2. Have students pair up with a partner to share their five ideas with each other. If any ideas appear on both lists, have students circle those.
3. Then, engage students in a whole-group discussion to ask them to share any ideas that were circled.
4. Generate a list of the circled ideas.
5. Ask for volunteers to share any ideas that were not circled that they think are really important to include in this topic.
6. Generate a separate list of those ideas.
7. At the end of making the two lists, have students copy down one single list of all the circled ideas and important ideas in their notebooks or on their paper.
8. Ask students individually to rank the ideas in the list from most to least relevant.
9. Ask for some students to share which term should be most relevant and why they think that is. Engage the whole group in discussion to arrive at consensus about the most relevant idea related to **Lake Superior** that they already know about or that came to mind during this exercise.

B. Bridge to Learning

Prepare food colored ice cubes. Fill a transparent container with hot water and carefully lower the colored ice cubes into the container using tongs. Show students how the ice cubes melt and colored water flows, mimicking thermal stratification seen in lakes. For comparison, introduce room temperature water dyed with another color at the surface using a pipette to see how it behaves differently than the cold water.

C. Close Reading a Video

Show this PBS LearningMedia video of **Global Ocean Currents** and ask the students to consider how water temperatures might affect ocean currents. Before students respond, have them do the following with a partner:

- **Review the video** and take notes on key points, visuals, and any questions or observations that arise.
- **Summarize the main content** of the video and identify the primary themes or messages it conveys.
- **Discuss the visual elements**, e.g., angle, lighting, etc., used in the video and how they contribute to its storytelling impact.
- **Explore the concept** of skiing in the video.
- **Engage in a discussion**, sharing insights, reactions, and interpretations of the video as it relates to the question.
- **Answer the question** in a class discussion, allowing partners to talk with other students and share ideas or ask follow-up questions to one another. Facilitate the discussion to arrive at a consensus about how water temperatures affect ocean currents and compare to their prior predictions.

D. Background Information Notes

Explain that you will be investigating more about **Lake Superior** before providing notes from the **Teacher Background Information**.

ACTIVITY 1: WATCH A GREAT LAKES NOW SEGMENT

This activity is a video discussion of a *Great Lakes Now* episode segment.

First, inform students that they will be watching a *Great Lakes Now* segment discussing how climate change is impacting the water temperature of Lake Superior. During the video they need to jot down four things they took away from the video using the **4 Notes Summary Protocol**.

Then, if students are not already familiar, introduce them to the 4 Notes Summary Protocol, which they will use after they finish watching the video, where they write down one of each of the following notes:

- **Oooh!** (something that was interesting)
- **Aaah!** (something that was an ah-ha moment)
- **Hmmm…** (something that left them wanting to know more)
- **Huh?** (a question they have afterward)

Next, have students watch the segment from episode 2404 of *Great Lakes Now* called **Lake Superior's Warming Waters**.

Last, have students complete their individual 4 Notes Summary and then discuss those in groups of 3-4 students.

Teaching Tip: Use the Student Handouts to help students organize their thinking in writing around each of the lesson protocols.

Post-Video Discussion

After the groups have had time to go over their 4 Notes Summaries, invite a handful of students to share out some of their notes, eliciting at least 1-2 of each of the 4 Notes and listing those somewhere for the whole group to see.

Ask students to turn back and talk with their groups to make connections between the *Great Lakes Now* video and what they remember from the warm-up activities.

How is what we saw in the video related to what we discussed earlier during the lesson launch activities?

After giving the groups some time to talk, bring the whole group back together for a shareout and discussion of ideas.

In this culminating discussion, the goal is to help students make connections between the video segment and what they discussed during the launch activities earlier in the lesson about what they knew about **Lake Superior.**

Once the discussion finishes, have each student write a "**Sum It Up**" statement in their notebooks. This is a single sentence that captures the big idea of what was just learned.

Have 2-3 students share out their **Sum It Up** statements before concluding this activity.

ACTIVITY 2: READ ABOUT NATIONAL PARKS DECARBONIZATION

In light of the rising temperatures in Lake Superior, the nearby national parks are trying to do something to combat the effects of climate change, which is warming the waters of the lake. Students will read about how the national parks around Lake Superior are taking significant steps to cut their carbon emissions by transitioning to renewable fuel sources in an effort to combat climate change.

In this activity, students will use a **Think Pair Square Protocol** for discussing what they will read about this very topic.

First, have students partner up and distribute the article **Lake Superior Is Warming Fast. Its National Parks Are Starting Work to Cut Fossil Fuels** by Izzy Ross from Interlochen Public Radio. Allow time for students to individually read the article, and have them jot down three things they took away from the article using the **Rose Thorn Bud Protocol**—in their notebook or using the handout.

Then, give students time after reading to discuss the article that they read with their partner. Have students share their rose, thorn, and bud with each other, including how those points connect to each other. The pair should come up with a statement to summarize all of their article takeaways.

Next, have two student pairs join up, standing near each other to form the four corners of a square, to discuss the article and what they talked about in their pairs. Encourage them to come to a consensus about which point they found most important or interesting in the article.

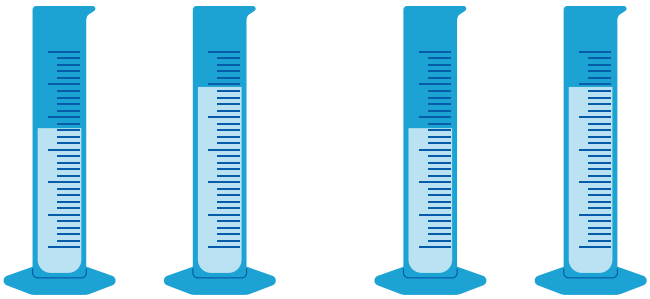
Last, have each group craft a summary statement of the most important point from their discussion and ask for a volunteer in each group to share that key point with the whole group. As student groups share their most important point, record their ideas on the board and have students copy the list of student ideas down into their notebooks. Once the shareout is complete, ask students to return to their groups and discuss one last question based on the article:

What do you see are the biggest costs and benefits of the proposed solutions to addressing the impact of climate change on Lake Superior?

You can keep this as a class discussion based on the article itself or, after giving the groups some time to discuss this question, invite them to further research the topics, points of interest, or themes discussed in the article by generating a research question, identifying additional sources, and presenting their findings.

Teaching Tip:
If the reading level of the article is going to be tough for some students to read individually, have partners or small groups read the article together aloud while each follows along, or the teacher might read the article to the entire class.

ACTIVITY 3: VISUALIZING THERMAL STRATIFICATION



The purpose of this activity is for students to understand how temperature affects water density and its implications for lake stratification.

Materials:

- Large (500mL) beakers or clear containers
- Thermometers
- Food coloring
- Ice
- Water
- Salt
- 100mL graduated cylinders

First, inform students that they will investigate thermal stratification—how temperature differences in waters affect the density and how the density of waters at different temperatures gets layered in lakes. Begin with a simple demonstration of adding vegetable oil to a graduated cylinder and then slowly adding some room temperature water to the same graduated cylinder by pouring it down the side of the graduated cylinder. Ask students to predict what will happen when the two are combined. Allow time for the two liquids to settle and then look again at the graduated cylinder to see that the oil layer floats atop the water later.

Then, explain to the students that the oil is less dense than water and review what that means by drawing particle diagrams* to represent the two substances (e.g., two boxes of the same size, one with more dots to represent the denser water, one with less dots to represent the less dense oil.) Make the connection that, due to molecular motion, water molecules at lower temperatures move less and are closer together, thus denser than warmer, faster, more spread out water.

Teaching Tip: If your students are less experienced with particle diagrams, practice a couple other examples first.

Next, have them partner up, get their materials, and conduct their experimental procedure:

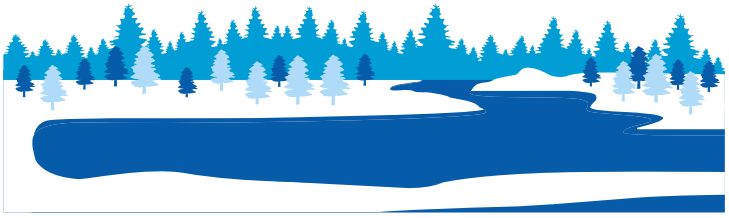
1. Fill one clear plastic container half with ice cold water (no ice), hot water in the other
2. Add a few drops of different colored food coloring to each container (e.g., blue for cold water and red for warm water) to visually distinguish between the two and mix
3. Use thermometers to measure and record the initial temperatures of both the ice water and the warm water
4. Slowly and carefully pour the hot colored water into the container with the ice water Tilt the ice water contain and slowly pour the hot water down the side to avoid splashing
5. Observe and note what happens initially
6. Observe the interaction between the warm and cold water over time. (Note that the warmer water stays on top of the cold water, indicating differences in density due to temperature.)
7. Continue observing the waters interact and mix over time every minute or two for about 10 minutes.

Salt Water Variation:

- For a variation, add salt to some other ice water to increase its density further and add a different (third) color. Repeat the pouring process by combining the three different waters and observe any differences in the behavior of the water layers.
- Note: students can also test this experiment out initially with the two temperatures and then design an experiment to layer several different colors based on density using a combination of salt and temperature.

Last, have students create a series of particle diagrams to represent a time lapse of what happened before, during, and later on after their experiment took place and the waters mixed for some time. Transfer those particle diagrams to chart paper or large dry erase boards, and then facilitate a class discussion to compare and connect observations and results of what happened at the macroscopic and microscopic level. Relate this to what happens with thermal stratification in Lake Superior.

ACTIVITY 4: INVESTIGATING LAKE SUPERIOR ALGAL BLOOMS



The purpose of this activity is for students to understand the conditions that lead to harmful algal blooms and their impacts on aquatic ecosystems and human health.

Materials:

- Clear plastic bottles
- Water
- Fertilizer (such as plant food or liquid fertilizer)
- Algae samples (available from an aquarium store)
- Light source (e.g., desk lamps or sunlight)
- Measuring spoons or syringes (for precise fertilizer amounts)
- Labels and markers (for identifying bottles)

First, inform students that they will be investigating how algal blooms form in an aquatic ecosystem and have been newly observed as of late in Lake Superior where they were never before seen. If students are unfamiliar with the concept of eutrophication or how algal blooms happen in a lake, review the concept, especially as it relates to the warming water temperatures in Lake superior, or check out **Lesson 1028** which focuses on it.

Next, have them partner up with someone for the lab, and begin setup by doing the following:

- Label each clear plastic bottle with a unique identifier (e.g., Bottle 1, Bottle 2, etc.)
- Fill each bottle with an equal amount of water, leaving some space at the top.
- Add different amounts of fertilizer to each bottle. For example:
  - Bottle 1: No fertilizer (control)
  - Bottle 2: 1 teaspoon of fertilizer
  - Bottle 3: 2 teaspoons of fertilizer
  - Bottle 4: 3 teaspoons of fertilizer
- Add a small amount of algae sample to each bottle. If using green food coloring, add the same amount to each bottle.
- Place all bottles under a consistent light source. Ensure they receive equal light exposure by arranging them uniformly.
- Over the course of a week, observe the bottles daily. Record any changes in water color, clarity, and the presence of algae growth.
- Take notes and photos daily to document differences and changes between bottles.
- Summarize findings at the end of one week using charts, tables, or graphs.
- As an extension you can have one set of trials for this experiment where you heat the water each day and see how it compares with the trials that only use room temperature water.

Then, have students discuss with one another, based on their data, what happened in the different bottles with the algae and different amounts of fertilizer. If you did a trial with heating the water each day, introduce that data some time after the discussion has already started about the regular trials, and have students discuss how that affects the mental model they were developing based on the data.

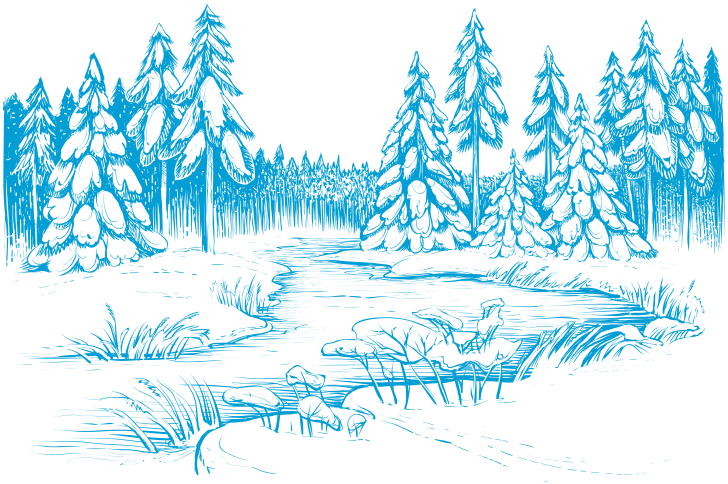
Last, discuss with students specific examples of algal blooms (like Lake Erie) that happen often and contrast that with those now starting to be observed in Lake Superior. Ensure that they understand that one contributing factor is warmer temperatures—both in the lake water and the atmosphere—because warmer weather means more rain/storms. More precipitation contributes to more runoff, which can fuel the algal blooms like adding the fertilizer to the bottles in the experiment. Additionally, warmer waters mean better conditions for algal growth.

Extend the discussion by having students create a process diagram or flow chart that explains how the algal blooms come about in a lake and how the warmer temperatures can contribute to them happening in Lake Superior.

***Teaching Tip**: Set this up and test this experiment out ahead of time, possibly even recording a video of your set up steps to use if you teach more than one class in a day.*

ACTIVITY 5: MODELING THE ALBEDO EFFECT

The purpose of this activity is for students to investigate the relationship between ice coverage, the albedo effect, and warming waters.



Materials:

- White printer paper
- Black construction paper
- Thermometers
- Ice cubes
- Sunny outdoor area or heat lamps
- Stopwatch or timer
- Notebook and pen for recording data

First, inform students that they'll be studying the albedo effect, which refers to the measure of reflectivity of a surface, specifically how much radiation (e.g., sunlight) is reflected by a surface compared to how much is absorbed. Remind them that lakes in colder climates, like Lake Superior, typically have a lot of ice and snow coverage in the winter months, which increases the albedo effect on the waters below.

Next, have students partner up and obtain the supplies needed to perform the experiment. Give them time to set up the experiment and review the procedure.

Procedure

1. Place a sheet of white paper and a sheet of black paper side by side in a sunny outdoor area or under a heat lamp.
2. Place an ice cube on each paper.
3. Start a timer to measure the melting time.
4. Record the temperature of the surface of each paper using thermometers at the start, periodically during the melting process, and at the end.
5. Note the time it takes for each ice cube to completely melt.
6. Record temperature readings and observe any differences in the rate of melting between the white and black paper.
7. Repeat the experiment with a mix of black and white paper checkered under the ice.

Last, have students summarize their findings on chart paper or a large dry erase board. Invite them to include a particle diagram to represent what they think was happening inside the system (e.g., the ice) and the surroundings at the smallest possible level (e.g., the molecular level). Invite groups to show their posters to each other and compare group data in order to arrive at a consensus about what happened.

Discuss with them how the albedo effect describes how surfaces with higher reflectivity (such as ice and snow) reflect more sunlight, while darker surfaces (such as water or vegetation) absorb more light, and thus more energy transfer into the system, warming the waters. This concept is critical in understanding various climate processes and the impact of surface characteristics on global temperature.

Have them update their particle diagrams to ensure it visually represents the albedo effect and the warming of the waters in Lake Superior due to less ice coverage in winter.

***Teaching Tip**: To extend the lab, different groups can try different sized pieces of ice; however, ensure that each group tests the same size piece of ice on both their white and their black sheets of paper within one set of trials.*

LESSON CLOSURE

After the conclusion of all the activities, help students to make connections* between everything they did in the lesson and what they learned overall.

A. Free Recall

Group students in pairs or triads (e.g., in groups of 2-3 partners) and distribute the **Free Recall Protocol handout**, Alternatively, you can have students do this in their notebooks. Set a 3-min timer and have students generate a list of everything they can remember learning about in this lesson related to the central topic of the lesson. This doesn't have to be in depth, just whatever each group can call to mind. Have them draw lines between any terms that relate to one another. After the timer finishes, give groups a chance to volunteer to share aloud 2-3 things from their free recall lists and any of the connections that they made with those. Jot down any ideas that come up multiple times during the shareout for the whole group to see.

B. Lesson Synthesis

Give students individual thinking and writing time in their notebooks to synthesize their learning, by jotting down their own reflections using the **Word, Phrase, Sentence Protocol.**

In the Word-Phrase-Sentence Protocol, students write:

- A **word** that they thought was most important from the lesson
- A **phrase** that they would like to remember
- A **sentence** that sums up what they learned in the lesson

C. Cool Down

After the individual synthesis is complete, students should share their synthesis with a partner.

After sharing their syntheses, have students complete a **3, 2, 1 Review** for the lesson with their partner, recording in their notebooks or, optionally, on exit ticket slips to submit, each of the following:

- **3 things** that they liked or learned
- **2 ideas** that make more sense now
- **1 question** that they were left with

Invite several students to share aloud what they wrote in either the synthesis or 3, 2, 1 Review.

Lastly, ask one student volunteer to summarize what has been heard from the students as a final summary of student learning.

**Optionally here, the teacher can revisit the learning objectives and make connections more explicit for students.*

Teaching Tip: Use the Student Handouts to help students organize their thinking in writing around each of the lesson protocols.

NAME: _____

A Word, Phrase, Sentence Protocol

What is a **word** that you thought was most important from this lesson?

What is a **phrase** that you would like to remember from this lesson?

What is a **sentence** that sums up what you learned in this lesson?

3, 2, 1 Review Protocol

What are **3 things that you liked or learned** from this lesson's activities?

-
-
-

What are **2 ideas that make more sense** now to you?

-
-

What is **1 question that you were left with** after this lesson?

-

NAME: _____

Free Recall Protocol

With 1-2 partners, generate a list of everything you can remember learning about in this lesson related to the central topic of the lesson. Draw lines between any terms that relate to one another.

NAME: _____

4 Notes Summary Protocol

OOOH!

Something that was interesting to you

AAAH!

Something that became clearer; an "ah-ha" moment

HMMM...

Something that left you wanting to learn more

HUH?

Something you questioned or wondered

Sum It Up Statement:

Summarize your group discussion about your 4 Notes Summaries below:

NAME: _____

Think Pair Square Protocol

THINK

Write down your own individual ideas

PAIR

Summarize what you and your partner discussed

SQUARE

Summarize what your group discussed

NAME: _____

Rose, Thorn, Bud Protocol

ROSE

Something that "blossomed" for you in your learning

THORN

Something that challenged your thinking or was difficult to understand

BUD

Something that's new and growing in your mind — a "budding" idea