# Crafting Engaging Science Environments

# CESE

*A Transformative Science Learning System*

This project is funded by the Education Innovation and Research grant program from the U.S. Department of Education.

Barbara Schneider, Joseph Krajcik, Sheneka Williams, & Clausell Mathis

Samantha Strachan

Lei Zhang

Elizabeth Tipton

Tony Latiker

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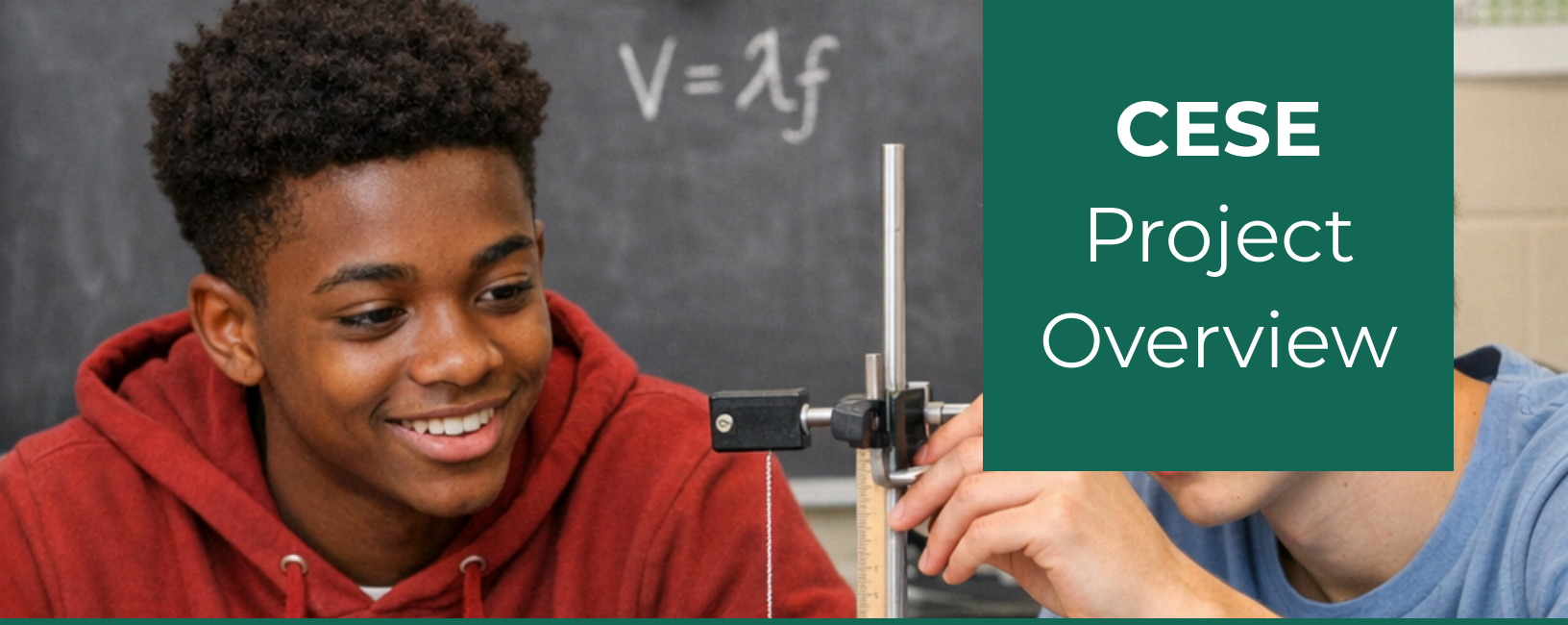



# CESE Project Overview

## PROJECT OVERVIEW

Crafting Engaging Science Environments (CESE) is an innovative science enrichment program for chemistry and physics classrooms providing learning and instruction to students in U.S. southern schools. This project works in partnership with Alabama A&M University, Winston-Salem State University, Jackson State University, Michigan State University, and Northwestern University.

CESE brings together project-based learning and science knowledge that improves students' science academic performance which keeps them on track to successfully complete their science courses. CESE will also strengthen their academic portfolio for admission to two- or four-year higher education institutions or postsecondary technical schools.

### PROJECT-BASED LEARNING

In project-based learning, students:

- Pursue solutions to meaningful questions.
- Explore why scientific phenomena occur, learn important disciplinary ideas, and engage in science practices.
- Participate in collaborative activities.
- Create artifacts that demonstrate learning.

### COMMUNITY-BASED APPROACHES

- Integrate students' community resources and experiences into the learning and teaching of science.
- Seek to make science meaningful to students by connecting it to their lived experiences and communities.

# Enhancing Science Learning and Instruction With **CESE**

## CESE Aligns with Mississippi's Goals

*Mississippi's Science Course of Study and Strategic Plans*

- **Student Experience:** Centers on high school chemistry and physics courses, preparing students with knowledge necessary for college admission, careers, or the workforce.
- **Teacher Development:** Offers high-quality, research-based, state standards-aligned professional development.
- **Student Learning:** Strengthens science foundations, boosts assessment performance, and inspires deeper engagement with real-world issues.
- **Teacher Learning:** Equips teachers with the content knowledge, instructional strategies, and resources needed to support students in meeting their learning goals.

## Benefits of CESE

- **Reduce Teacher Preparation Time and Support Lesson Planning:** Supplies ready-to-use enrichment materials, including teacher guides with resources, lessons, assessments, and student handouts.
- **Flexible Enrichment Materials:** Enables teachers and school leaders to adapt the materials to meet their needs and continue to use them year after year.
- **Year-Long Support for Teachers and Schools:** Provides honorariums to schools and teachers, professional development, continuing education credits, and collaboration opportunities for teachers.
- **Community Building:** Meets the needs and experiences of students and teachers in the South, fostering continuous collaboration and strenghening the community.
- **Technology:** Embeds technology in instruction, modeling, and assessments to enhance student learning.
- **Evaluated Independently:** Measures science learning with rigorous independent assessments.

# CESE School, Student, and Teacher Benefits

## PROGRAM DETAILS

With the right resources and support, high-quality chemistry or physics classrooms can ensure students thrive in society and the workplace. To support this vision, CESE provides a comprehensive program that includes innovative, hands-on experiences for teachers and students, professional development for teachers, and a wealth of tangible classroom resources that enhance science learning and instruction.

## CESE PROVIDES THESE BENEFITS TO YOUR SCHOOL

**Honorarium:** Schools and teachers receive an honorarium for their participation.

**Comprehensive Program Aligned with State Standards:** Teachers access innovative, hands-on experiences that align with state standards.

**Essential Materials:** All project materials will be provided to the teachers, ensuring that they have everything they need (e.g., technology, digital learning materials, games, lab equipment, and supplies).

**Additional Resources and Supports for Teachers:** Teachers will receive continuing education credits, access to a helpline, and opportunities to expand their professional science networks.

## STUDENT BENEFITS

Increase:

- Science achievement scores
- College and career ambitions
- Engagement in science

Access to:

- Hands-on science experiences
- Strategies for science learning and test taking
- Post-secondary application, enrollment, and career planning resources

## SCHOOL EXPECTATIONS

**Ensure Access to Chemistry and Physics Teachers:** Teachers have the opportunity to attend three 2-day, in-person professional development sessions and periodic online meetings.

**Aid in the Collection of Student, Teacher, and Administrator Data:** Assist CESE team in accessing student, parent, teacher, and administrator consent forms and relevant data. All CESE activities, materials and assessments meet *Family Educational Rights and Privacy Act (FERPA)* requirements for students, parents, teachers, and administrators.

## PROJECT TIMELINE

**07/01/25** Start Date

**06/30/26** End Date

## PROJECT SUSTAINABILITY

**Retention of Guides & Materials:** Schools will keep all the curriculum materials, enabling teachers to use them year after year without additional cost or effort.

## CONTACT INFORMATION

For more information or any questions, please don't hesitate to reach out to:

**CESE Project Director**
**Dr. Shimeng Dai: daishime@msu.edu**

# CESE
# Post-Project Benefits

## SCHOOL BENEFITS

**Retention of Guides & Materials:** Schools keep all the science materials without additional costs or effort.

**Retention of Partnership with State University:** University partners can continue to provide professional development opportunities for teachers and administrators.

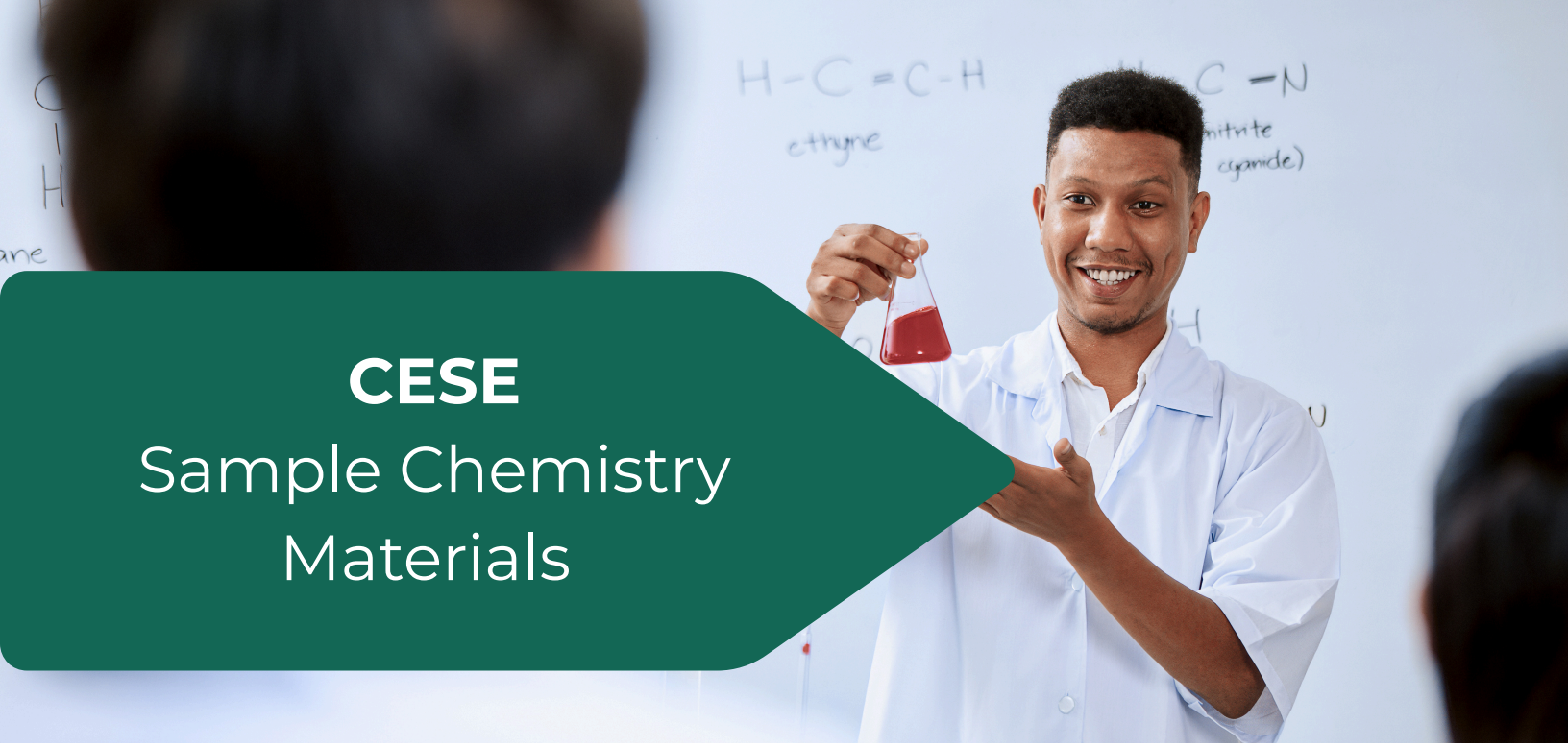
## STUDENT BENEFITS

**Post-Secondary Education Access Resources:** Students will have access to resources for two- and four-year postsecondary institutions, including application support, college counseling services, financial aid planning resources, and connections to partnering post-secondary institutions, including career and technical programs.

**Career Planning Support:** Students will receive career planning resources which are aligned with their education and professional aspirations.

Two Exemplar Program Experiences:
One in Chemistry and One in Physics

**CESE**



# CESE
# Sample Chemistry Materials

**Contents**

## Driving Question:
## *Why does my stomach sometimes hurt when I drink energy drinks?*

## Lesson List

**Lesson 1:** Why does my stomach sometimes hurt when I drink energy drinks?
**Lesson 2:** How could the different parts of an energy drink cause stomach pain?
**Lesson 3:** How could the different parts of an energy drink all contribute to stomach pain?
**Lesson 4:** What are acids and bases?
**Lesson 5:** Why is acid important for digestion?
**Lesson 6:** Does temperature matter to the reaction?
**Lesson 7:** Does concentration matter to the reaction?
**Lesson 8:** Why does changing the temperature and concentration of reactants increase the rate of a chemical reaction?
**Lesson 9:** How might I feel if there is too much acid in my stomach?
**Lesson 10:** What can I do to reverse the amount of acid in my body?
**Lesson 11:** What do I do if I can't reverse a chemical reaction in my body?
**Lesson 12:** Why does my stomach sometimes hurt when I drink energy drinks?

| Core Curriculum Elements | | | | |
|---|---|---|---|---|
| **Lesson Question** | **Phenomenon** | **Scientific Practice(s)** | **What We Figured Out (Core Idea + Crosscutting Concept)** | **3-Dimensional Learning Performance** |
| Each lesson has a student-friendly guiding question that stems from the driving question. The question or sub-question should spark curiosity and feel relevant or meaningful. | Each lesson has a phenomenon. The phenomenon is a real-world event or observation that students can see, feel, or relate to. It should drive the need to find a solution. | Each lesson has scientific practices that focus on what students *do* to explore the phenomenon. Scientific practices can include investigations, modeling, arguing evidence, analyzing data, etc. Scientific practices connect to the Disciplinary Core Idea (DCI) and help students build understanding. | In each lesson, "what we figured out" summarizes what students should figure out during the lesson. This links to a piece of the DCI and a relevant CCC, such as cause & effect, systems, or patterns. Consider: What did students learn that will motivate the next step in the unit? | Each lesson has a lesson-level learning goal that integrates: Scientific Practice, DCI, and CCC. It represents what students should be able to do and explain by the end of the lesson. |

# Lesson 1

**Guiding Question:** Why does my stomach sometimes hurt when I drink energy drinks?

**Phenomena:** Different parts of the digestive system sometimes hurt when people ingest energy drinks.

**Brief Description:**

- ***Introducing the Driving Question:*** Introduce students to the unit by reading articles about energy drinks. Students will generate questions about the potential pros and cons of consuming energy drinks, which leads to the presentation of the Driving Question (DQ).
- ***Investigating Ingredients:*** Working in groups, students will analyze energy drink labels and conduct online research to identify key ingredients. They ask questions and begin constructing a Driving Question Board (DQB) to organize their inquiries.
- ***Forming Hypotheses:*** Students develop initial hypotheses about which ingredients might have the greatest impact on the stomach. They begin documenting their ideas and progress on an Activity Summary Board (ASB).
- ***Community Connection & Wrap-Up:*** To extend learning beyond the classroom, students are prompted to ask family or community members about common remedies or strategies for easing stomach discomfort.

**Materials & Teacher Preparation:**

- ***Unlabeled Energy Drink Samples:*** Remove or cover labels or transfer contents to unmarked containers. Save labels for a later activity.
- ***Classroom Boards:*** Construct an Activity Summary Board (ASB) that will accompany the class throughout the unit. Have a segment of the board dedicated to home remedy stories and/or suggestions that the students will bring to class. Additionally, provide students with materials and tools to construct the Driving Question Board (DQB) as they see fit.
- ***Safety guidelines:*** Standard classroom safety protocol.

| Scientific Practice(s) | What We Figured Out | 3-Dimensional Learning Performances |
|---|---|---|
| Asking Questions and Defining Problems. | Students figure out that chemical reactions occurred in the digestive system that can be affected by the ingredients in energy drinks causing discomfort.<br><br>Students make connections between the macroscopic consequences (e.g., stomach pain) of microscopic interactions (chemical reactions) inside the stomach. | Students ask questions about the components of energy drinks and what reactions can occur when they are ingested in the stomach to identify patterns associated with stomach pain or discomfort.<br><br>*Look for: Students generating questions, identifying key ingredients and patterns from case studies, forming hypotheses about ingredient-stomach interactions, and connecting personal experiences to the driving question.* |

# Lesson 1: Why does my stomach sometimes hurt when I drink energy drinks?

**Lesson Summary**: In this lesson, students are introduced to the driving question of the unit. Students explore some effects from case studies of energy drinks and how specific ingredients in energy drinks might cause discomfort in the digestive system, particularly the stomach. They engage in noticing patterns and asking questions through the case studies and component analysis of energy drinks, to hypothesize what occurs at the molecular level when these ingredients are ingested. Through this, students begin to wonder about the chemical reactions that are occurring in their stomach.

**Lesson-level learning goals**: Students ask questions about the components of energy drinks and what reactions can occur when they are ingested in the stomach to identify patterns associated with stomach pain or discomfort.

**Lesson-level 3-dimensional components**

| Disciplinary core ideas | Crosscutting concepts | Science and engineering practices |
|---|---|---|
| PS1.B: Chemical Reactions<br><br>Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. | Patterns<br><br>Students make connections between the macroscopic consequences (e.g., stomach pain) of microscopic interactions (chemical reactions) inside the stomach. | Asking questions and defining problems.<br><br>Students formulate questions about energy drink ingredients and their effects related to pain in the digestive system that can be investigated and explore. |
| Students figure out that chemical reactions occurred in the digestive system that can be affected by the ingredients in energy drinks causing discomfort. | ***Look for***<br>• *Students formulating questions about why energy drinks might cause stomach pain.*<br>• *Students identifying specific ingredients or effects that stand out from the case studies analysis.*<br>• *Students identifying patterns between ingredient types, quantities, and possible discomfort, forming hypotheses about how specific ingredients interact with the stomach environment.* | |

| | |
|---|---|
| | • *Students sharing personal or familiar experiences with the driving question, discussing instances of stomach discomfort related to energy drink consumption.* |

**Connection to other lessons in the unit**: This is the first lesson of the unit. Students explore the phenomena framing the unit and start making questions related to the energy drinks effects and its composition. In this lesson, they explore how energy drink ingredients might be related to digestive system discomfort.

**Evidence Statement(s)**:

- Students record questions and wonders related to energy drink consumption and ingredients that may lead to stomach discomfort on the Driving Question Board (DQB).
- Students present their initial hypotheses on the Activity Summary Board (ASB), describing possible causal mechanisms between specific energy drink ingredients and stomach pain.
- Students collect family or community home remedies for stomach discomfort, connecting cultural knowledge to scientific concepts and identifying any common patterns across suggested remedies.

**Materials and Preparation**

Group Materials:

- Disclaimer printouts detailing potential health impacts of energy drinks (e.g., NHFS articles, CDC info)
- Example of Nutrition facts tables or nutritional/component information from energy drinks cans (no labels)
- Online access for identifying energy drink components characteristics.
- Large cardboard for ASB (Activity Summary Board) and DQB (Driving Question Board)
- Student handout to collect family or community remedies.

**Safety guidelines**

Standard classroom safety protocol.

**Suggested time and sequence of the lesson**

| Time (min.) | Activity | Setting |
|---|---|---|
| 15 | Introduction to the Driving Question and framing the unit's phenomena | Whole class |
| 25 | Exploring Case Studies and Nutrition Facts tables from energy drinks | Small groups |

| Time (min.) | Activity | Setting |
|---|---|---|
| 15 | Building the Driving Question Board and Activity Summary Board | Small groups |
| 5 | Wrap up: Summarize the lesson | Whole class |

**Suggested instructional sequence**

Lesson Component 1: Introduction to the Driving Question and framing the unit's phenomena

1. Begin the lesson by showing a short, engaging video, image, tell students a brief story or present a relatable case study involving someone experiencing stomach pain after consuming an energy drink. Highlights the popularity of energy drinks and their potential side effects. Options include:
   a. A short video featuring someone describing their experience with energy drinks or general effects on body (Option 1 and Option 2).
   b. A striking image, such as an energy drink advertisement (Option 1 or Option 2).
   c. Tell a story of a teenager preparing for a sports event or staying up late for a study session and turning to an energy drink for an energy boost, only to experience discomfort afterward.
2. Allow students to share their experiences and observations in small groups or as a whole class. This creates an opportunity for students to connect the topic to their lives. Ask students:
   a. What energy drinks have you seen or consumed? How often do you or people you know drink them?
   b. Have you ever felt stomach pain, heartburn, or discomfort after drinking an energy drink? If so, what did it feel like?
3. Present the Driving Question to students: *Why does my stomach sometimes hurt when I drink energy drinks?* Briefly discuss what they think this question is asking them to consider, focusing on both the ingredients in energy drinks and their effects on the body. Some questions might be:
   a. What do you think this question is asking us to explore?
   b. What might be happening inside your body—particularly your stomach—when you consume an energy drink?
   c. What ingredients in energy drinks could be causing discomfort?

Lesson Component 2: Exploring Case Studies and Nutrition Facts tables from energy drinks

1. Divide students into small groups of 3-4. Distribute a short set of articles or case studies on the effects of energy drinks. Options might include:
   a. A summary article from a health organization (e.g., CDC) discussing potential side effects.
   b. A case study or real-life news story about someone experiencing negative effects from energy drinks.

   c. An article summarizing the ingredients typically found in energy drinks and their potential health impacts.
   d. A video: Energy Drinks: Why Are They Sending So Many People to the ER?
2. As students review the materials, encourage them to highlight any ingredient or effect that stands out to them.
3. Ask students to think about and discuss: What questions do you have after exploring these materials? Guide students toward asking questions that focus on:
   *a. What ingredients in energy drinks might be causing discomfort.*
   *b. How these ingredients might interact with the stomach or digestive system.*
   *c. The differences between safe amounts and potentially harmful quantities.*
4. Ask them to capture some of these questions on the board. Sharing their questions will guide their inquiry throughout the unit, leading to an understanding of how science explains the sensations they feel in real life.

**Tips for teachers**

Be sure to encourage students to think critically about the sources they've read. Prompt them to question the reliability and background of each article or case study.

- Highlight the relevance of this exploration to their lives, emphasizing that the lesson will help them make informed choices regarding what they consume.

Encourage open-ended questions, like:

- *What is in energy drinks that could cause stomach pain?*
- *Why might some people feel discomfort and others not?*
- *How might the ingredients in energy drinks interact with our bodies?*

Explain that they'll begin investigating the ingredients in energy drinks, starting with formulating questions about what's inside them and hypothesizing their effects with the identification of patterns.

Encourage curiosity by prompting students to think deeply about why certain ingredients are used in energy drinks and what effects they might have. Guide students to see how asking questions is foundational to scientific inquiry and helps them build a deeper understanding of real-world phenomena.

5. Once they have some questions on the board about the Case Studies and they share what they found with the whole group, and what they wonder, provide each group with energy drink cans (without labels), ingredient lists or Nutrition facts tables and ask them to search online information about the common components found in energy drinks (e.g., caffeine, sugar, citric acid, taurine).
6. Explain that they will be examining these ingredients to generate questions about how they might interact with the stomach environment.

7. Ask each group to read the ingredient lists carefully and write down any questions that come to mind. Guide them with prompts to focus their questions on:
   a. *The nature of each ingredient (e.g., What is caffeine, and how does it affect the body?).*
   b. *Potential effects of these ingredients on the stomach (e.g., Why might citric acid cause discomfort in the stomach?).*
   c. *Quantities and combinations (e.g., How much of each ingredient is in the drink? Could large amounts lead to discomfort?).*
8. Remind students that they should connect their questions to possible effects on the stomach, especially relating to digestion and chemical reactions.

<u>Lesson Component 3: Building the Driving Question Board and Activity Summary Board</u>

1. Bring the class back together and ask each group to share some of their most interesting questions.
2. Begin constructing a Driving Question Board (DQB) by adding students' questions. This board will remain in the classroom for the duration of the unit, allowing students to add new questions and refine existing ones as they progress.
3. Encourage them to consider open-ended questions that will guide their investigations in future lessons. Because this is for high school sophomores or juniors, push students to write questions that connect an independent variable (e.g., energy drinks or a specific ingredient like caffeine or sugar) with the dependent variable (stomach pain or discomfort). For example, ask:
   a. *How might the amount of citric acid (independent variable) influence stomach pain (dependent variable)?*
   b. *What effect could caffeine levels have on the stomach environment and pain?*
4. Remind students that the Activity Summary Board (ASB) is a place where they'll record observations, summaries, hypotheses, and new learnings as they investigate the driving question. Explain that they'll start by adding their initial hypotheses about which ingredients might cause stomach pain and why.
5. Ask each group to consider the whole group questions they formulated into the DQB. Allow them to review the question and explore with them: *What patterns did you notice? What are the most common questions? What are the most common characteristics in substances related to discomfort by energy drinks?*
6. Then ask students to come up with at least one hypothesis about how a specific ingredient might contribute to stomach discomfort using the pattern they identify. Encourage them to explicitly connect the independent variable (ingredient type or concentration) to the dependent variable (stomach pain). For example: *"We think that caffeine (independent variable) might cause discomfort because it stimulates acid production, which could increase stomach pain (dependent variable)."* "Our hypothesis is that citric acid interacts with stomach acid to lower pH, causing pain."
7. Encourage students to use sentence starters, such as "We think that [ingredient] might cause discomfort because…" or "Our hypothesis is that [ingredient] could interact with stomach acid in a way that causes pain." As groups share, write each hypothesis on the ASB, encouraging students to explain their reasoning.
8. Finally, create a section on the ASB labeled Home Remedies for students to contribute community-based solutions to stomach discomfort. Invite students to bring in stories or tips from family or friends about remedies they use for stomachaches (like herbal teas,

ginger, etc.). Explain that these remedies will be explored later in the unit as part of understanding diverse perspectives on managing stomach pain.

**Tips for teachers**

Guide students in developing plausible hypotheses, reminding them that their hypotheses don't have to be "correct" but should be grounded in reasoning based on the ingredients they've researched and the information they explore.

On the other hand, the *Home Remedies* section adds a culturally responsive element, allowing students to connect their learning to family and community knowledge. Encourage students to value diverse knowledge by bringing home remedy stories, supporting connections between scientific and cultural understandings.

Lesson Component 4: Wrap up: Summarize the lesson

1. Summarize the main points of the lesson, emphasizing the process of asking questions, forming hypotheses, and starting to make connections between ingredients in energy drinks and potential effects on the stomach.
2. Review some of the questions and hypotheses posted on the ASB and DQB to reinforce the connection between their ideas and the driving question.
3. Remember students to talk to family members or others in their community about common ways to alleviate stomach pain, especially focusing on any traditional or home remedies using the handout provided in class. Encourage them to ask why these remedies are used and how they're believed to work. Ask students to bring this information to the next class, where they'll add it to the Home Remedies section of the ASB.

# UNIT 5 – ENERGY DRINKS

HS-PS1-5: Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.
HS-PS1-6: Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.
HS-PS2-6: Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

## ASSESSMENT RUBRICS

**Question 1**

To verify how much active ingredient there is in an antacid tablet, students crushed a single 750 mg tablet and dissolved it in 100 mL of water. They poured from the solution into three beakers, added a few drops of indicator to each beaker and measured the volume of acid solution added until its color changed (a titration experiment). They achieved the following results:

| Iteration | Volume of antacid solution [mL] | Volume of HCl 0.05 M until color change [mL] |
|---|---|---|
| 1 | 10 | 206 |
| 2 | 10 | 192 |
| 3 | 10 | 202 |

The students then decided to repeat the experiment with an expired tablet – one that is past its due date. They received the following results:

| Iteration | Volume of antacid solution [mL] | Volume of HCl 0.05 M until color change [mL] |
|---|---|---|
| 1 | 10 | 157 |
| 2 | 10 | 148 |
| 3 | 10 | 151 |

- Assuming the active ingredient in the antacid table is Calcium Carbonate ($CaCO_3$), calculate the mass of the active ingredient in one tablet from the first table.
- Using the CER method, determine which tablet – regular or expired – is more effective at neutralizing stomach acid.

**Exemplar Response:**

Calculation of the mass of active ingredient in one tablet (using the average volume of HCl):

$$n(HCl) = C \times V = 0.05M \times 200 \cdot 10^{-3}L = 0.01mol$$

$$CaCO_{3\,(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2\,(aq)} + CO_{2\,(g)} + H_2O_{(l)}$$

$$n(CaCO_3) = \frac{1}{2}n(HCl) = 5 \cdot 10^{-3}mol$$

$$m(CaCO_3)_{Unexpired} = n \times M_W = 5 \cdot 10^{-3} mol \times 100\,{}^{gr}/_{mol} = 0.5gr = \boxed{500mg}$$

**Claim:** The regular antacid tablet is more effective than the expired antacid tablet at neutralizing stomach acid.

**Evidence:** the volume of acid needed to change the color of the expired antacid solution is, on average, smaller than the one required for the same change in the regular antacid solution. This can also be shown with calculation of the active ingredient's mass for the expired tablet:

$$n(HCl) = C \times V = 0.05M \times 152 \cdot 10^{-3} L = 0.0076mol$$

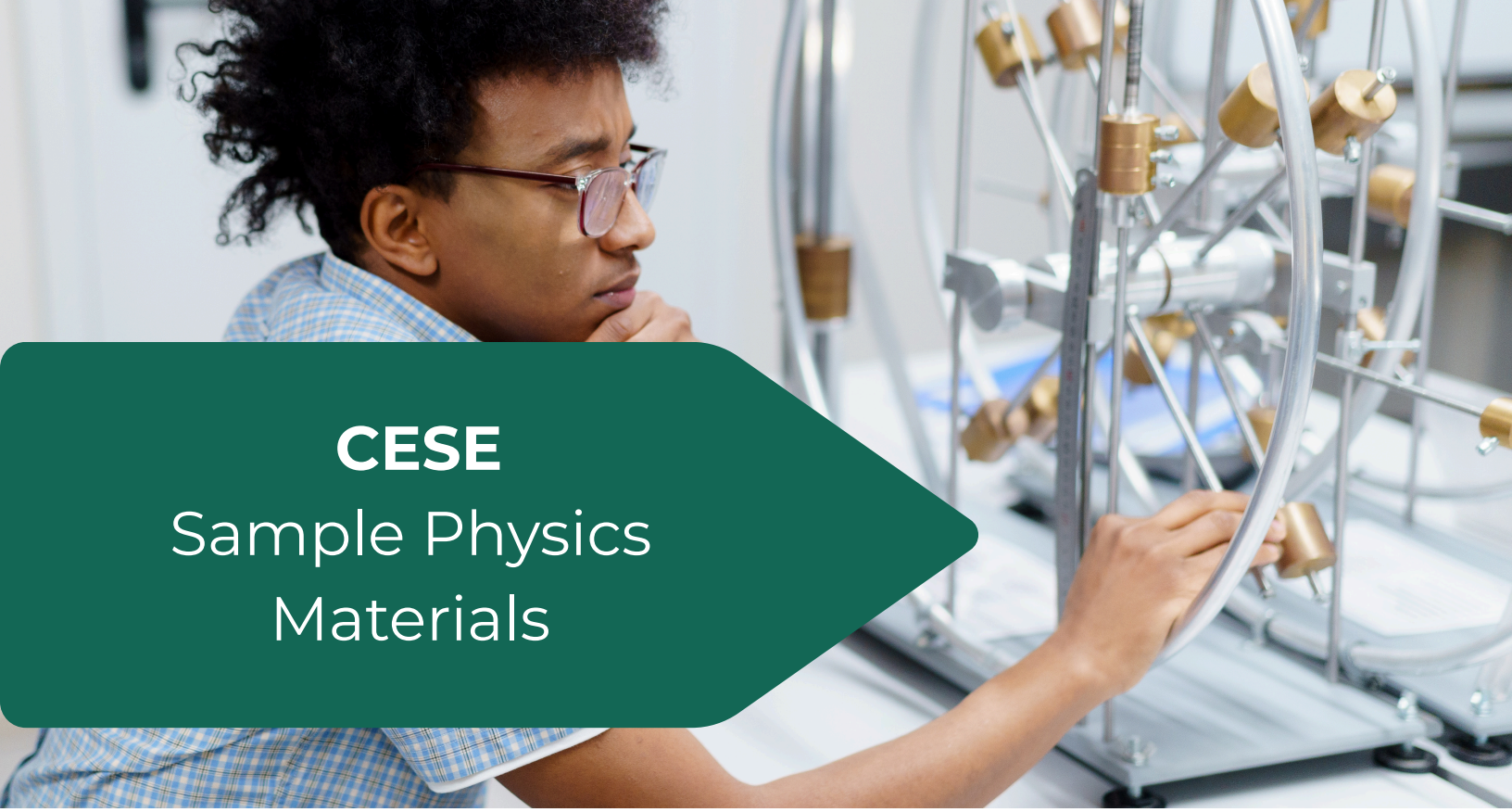
$$CaCO_{3\,(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2\,(aq)} + CO_{2\,(g)} + H_2O_{(l)}$$

$$n(CaCO_3) = \frac{1}{2} n(HCl) = 3.8 \cdot 10^{-3} mol$$

$$m(CaCO_3)_{Expired} = n \times M_W = 3.8 \cdot 10^{-3} mol \times 100\,{}^{gr}/_{mol} = 0.38gr = \boxed{380mg}$$

**Reasoning**: the solution changes color when all the base has reacted with the acid, and every drop of added acid adds to the concentration of hydrogen ions in the solution, changing the conditions and making the indicator change color. The higher the volume of acid needed for a color change for a given volume of a tablet solution, means that there is more active ingredient in that tablet (higher mass), which in turn makes it more effective.

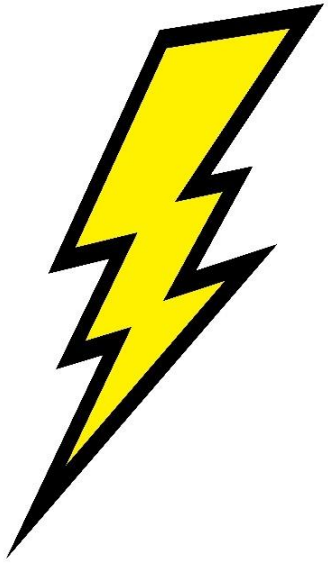
For the same volume, the expired tablet's solution changes color after the addition of a lower volume of acid, which means it contains less active ingredient for the same amount of tablet, and therefore it is less effective.



# CESE
# Sample Physics Materials

**Contents**

# Driving Question:
## *How can we protect people, animals, and the environment from the hazards of lightning?*



## Lesson List

**Lesson 1:** How can we protect people, animals, and the environment from the hazards of lightning?
**Lesson 2:** How does understanding how lightning occurs help protect me and my community?
**Lesson 3:** Why do some electrostatic interactions result in small sparks that can give me a little shock, while others result in extreme shocks, like lightning bolts, that can significantly harm me and my community?
**Lesson 4:** How does exploring the mathematical relationship between variables affecting electrostatic forces help me to predict the strength of electrical forces that can lead to lightning strikes?
**Lesson 5:** How can I use the results of my investigations to build a mathematical model that accurately predicts electrical forces that result in lightning strikes that can harm my community?
**Lesson 6:** What changes in conditions lead to the formation of sparks (small shocks) or lightning bolts/strikes?
**Lesson 7:** Does concentration matter to the reaction?
**Lesson 8:** How can we design a lightning protection solution to protect people and the environment where we live from the hazards of lightning?

| Core Curriculum Elements | | | | |
|---|---|---|---|---|
| **Lesson Question** | **Phenomenon** | **Scientific Practice(s)** | **What We Figured Out (Core Idea + Crosscutting Concept)** | **3-Dimensional Learning Performance** |
| Each lesson has a student-friendly guiding question that stems from the driving question. The question or sub-question should spark curiosity and feel relevant or meaningful. | Each lesson has a phenomenon. This phenomenon is a real-world event or observation that students can see, feel, or relate to. It should drive the need to find a solution. | Each lesson has scientific practices that focus on what students *do* to explore the phenomenon. Scientific practices can include investigations, modeling, arguing evidence, analyzing data, etc.<br>Scientific practices connect to the Disciplinary Core Idea (DCI) and help students build understanding. | In each lesson, "what we figured out" summarizes what students should figure out during the lesson. This links to a piece of the DCI and a relevant CCC, such as cause & effect, systems, or patterns. Consider: What did students learn that will motivate the next step? | Each lesson has a lesson-level learning goal that integrates: Scientific Practice, DCI, and CCC. It represents what students should be able to do and explain by the end of the lesson. |

# Lesson 1

**Guiding Question:** How does lightning impact people, animals, and the environment where I live?

**Phenomena:** Effects of lightning: fires, explosions, damage to circuits, electronics, and plumbing, formation of fulgurite rock, earth-atmosphere electrical balance, and ozone-producing chemicals

**Brief Description:**

- ***Introducing the Driving Question:*** This lesson introduces the Driving Question (DQ) and engages students in generating questions about the phenomena of lightning through videos, making predictions about the nature of lightning based on its effects, weather reports, data, and stories of their own experiences. The Driving Question and student-generated questions will be revisited in subsequent lessons throughout the lesson.

- ***Wrap-Up:*** Students obtain, evaluate, and communicate information about the effects of lightning and make predictions about the nature of lightning during this lesson that they will continue to return to throughout the lessons.

**Materials & Teacher Preparation:**

- ***Van De Graaff Generator:*** Begin by touching the smaller sphere, which is connected to the grounding wire, to the large dome. Turn the knob to the left (counterclockwise). Switch on the Van de Graaff generator. Gradually turn the knob to the right (clockwise) to start the motor, which will move the belt. Once the charge has built up on the dome, carefully move the small sphere away. Ask a student to dim the lights so the sparks are easier to see. Move the small sphere around the dome in various positions to display the sparks to everyone.

- ***Classroom Boards:*** Construct a Driving Question Board (DQB) for posting the overall Driving Question, student questions and student artifacts. Padlet can be used as a virtual DQB for students to post questions.

- ***Safety guidelines:*** Ensure that the large sphere is connected to the earth/grounded after use either by using a wire or the small sphere. The current produced by the machine causes problems with people with heart problems or pacemakers. Warn the students to be aware of the small shocks they will experience during the experiment.

| Scientific Practice(s) | What We Figured Out | 3-Dimensional Learning Performances |
|---|---|---|
| Asking Questions and Defining Problems<br><br>Obtaining, Evaluating, and Communicating Information | Students will obtain and combine information from reliable media to identify and describe the effects of lightning strikes on people, animals, and the environment with a focus on the cause-and-effect relationships. | Students generate and refine questions about the causes, characteristics, and effects of lightning strikes.<br><br>*Look for: Students sharing their observations and experiences with lightning to generate and refine open-ended questions about the causes, characteristics, and effects of lightning strikes in the environment, particularly related to the driving question.* |

## *Lesson 1: How does lightning impact people and the environment where I live? What can we learn about lightning from these effects?*

| | |
|---|---|
|  | Link: https://pixabay.com/photos/lightning-red-nature-coloured-2702168/<br><br>Image: Pixabay |

**Lesson-level Driving Question(s)**

How does lightning impact people and the environment where I live? What can we learn about lightning from these effects?

**Summary**
This lesson introduces the driving question and engages students in generating questions about the phenomena of lightning through videos, making predictions about the nature of lightning based on its effect, weather reports, data, and stories of their own experiences. The Driving Question and student-generated questions will be revisited in subsequent lessons throughout the unit. Students will obtain, evaluate and communicate information about the effects of lightning and make predictions about the nature of lightning during this lesson that they will continue to return to throughout the unit.

**Lesson-level learning goals**

Students will generate and refine questions about the causes, characteristics, impact and effects of lightning strikes.

Students will obtain and combine information from reliable media to identify and describe the effects of lightning strikes on people, the environment, and structures with a focus on the cause-and-effect relationships (between lightning strikes and natural hazards such as fires, deaths, and damage to electrical systems, as well as the role of lightning in balancing electrical charges in the Earth and initiating the formation of different chemicals and rocks).

**Lesson level 3-dimensional components:**

<table>
<tr><th>Disciplinary Core Idea(s)</th><th>Crosscutting Concept(s)</th><th>Science and Engineering Practice(s)</th></tr>
<tr><td>ESS3.B: Natural Hazards: Lightning is a natural hazard that poses risks to people, animals, and the environment.<br><br>HS-ESS3-1: Natural hazards and other geologic events have shaped the course of human history.</td><td>Cause and Effect<br>Empirical evidence is required to make claims about specific causes and effects. They suggest cause and effect relationships to explain and predict behaviors in complex natural and designed systems.<br>They also propose causal relationships by examining what is known about smaller scale mechanisms within the system. They recognize changes in systems may have various causes that may not have equal effects.</td><td>Asking Questions and Defining Problems<br>Ask questions that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information.<br>Note features, patterns, or contradictions in observations and ask questions about them.<br><br>Obtaining, Evaluating and Communicating Information<br>Use words, tables, diagrams, and graphs (in hard copy or electronically), and mathematical expressions, to communicate their understanding or ask questions about a system under study.<br><br>Read scientific and engineering text, including tables, diagrams, and graphs, commensurate with their scientific knowledge and explain the key ideas being communicated.<br><br>Engage in a critical reading of primary scientific literature (adapted for classroom use) or of media reports of science and discuss the validity and reliability of the data, hypotheses, and conclusions.</td></tr>
<tr><td>Students are figuring out the effects of lightning strikes on their environment.</td><td colspan="2">Look for students…<ul><li>Sharing their observations and experiences with lightning to generate and refine open-ended questions about the causes, characteristics, and effects of lightning strikes in the environment, particularly related to the driving question.</li><li>Collaboratively generating questions about the impact of lightning and protection from its hazards.</li><li>Collaboratively obtaining and combining information from reliable media to identify and describe the effects of lightning strikes on people, the environment, and structures</li></ul></td></tr>
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| | |
|---|---|
| | with a focus on the cause-and-effect relationships (between lightning strikes and natural hazards such as fires, deaths, and damage to electrical systems, as well as the role of lightning in balancing electrical charges in the Earth and initiating the formation of different chemicals and rocks). |

**Evidence statement(s)**

- Student generated questions about the phenomena might include the conditions that lead to lightning strikes, how lightning taking place, the variables/factors (e.g., size or color of the clouds, weather conditions, wind, the distance between the clouds and the place where lightning strikes) that impact the strength of lightning strikes, methods and techniques for lightning protection.
- Students first lists the effects of lightning (e.g., lightning-initiated fires; tree explosions, damages to their circuits; electronics and plumbing, formation of fulgurite rock, maintaining the earth-atmosphere electrical balance, and/or strikes creates ozone-producing chemicals as well as other effects they may discover.) Then they will make predictions about the nature of lightning based on these impacts.

**Connection to other lessons in the unit**

This lesson introduces the key phenomena and driving questions and prompts students to generate their own questions and predict the nature of lightning. Teachers share facts about the prevalence of lightning and its effects. The driving question, student-generated questions, and list the cause and effects of lightning will be revisited in lessons throughout the unit.

**Preparation**

Driving Question Board (DQB)- Prepare an area of the class for posting the unit Driving Question, student questions as well as student artifacts. Padlet can be used as a virtual DQB as well for students to post questions.

The Driving Question for this unit on electrostatic forces is, “How can we protect people, animals, and the environment from the hazards of lightning? Post this question prominently on the Driving Question board (DQB) before beginning Activity 1.4. Make sure DOB is addressed and reviewed in each lesson, together with the Activity Summary Board (ASB). For a detailed description of the Driving Question Board and the Activity Summary Board- see this DQB folder and this article Touitou et al., 2018.

**Tips for teachers- note on discussions**

Discussions play a key role throughout this curriculum. To get students to share ideas and engage in lively discussions, it is important to set a tone that all ideas are important. The following types of questions can be used throughout all these discussions to encourage a variety of students to share their thoughts.

Suggested questions to support building classroom community:

- Who else has a different idea or description?
- Who else has a similar idea or description?
- Who agrees or disagrees with that idea? Explain.
- What questions could we ask or investigate to sort out the differences in people's ideas?

**Equipment and materials**

Per group/ student:

- Post-it Notes
- Data/Reports on the frequency of lightning and its effects
  - (Lightning Report (2020), Interactive Lightning Report 2023
  - The impact of lighting, its hazards
  - Lightning Strike Victim Data
  - Five Ways Lightning Strikes People
  - NASA related source
  - Number of lightning Strikes by States
  - Lightning Counts by States
  - Dangerous Thunderstorm Alerts by Top 10 States
  - Thunder Hours by Top 10 States

Per class:

- Van de Graaff Generator
- Projector or Class TV for viewing videos
  - Videos of lightning storms and their effects
  - Video of News about lightning storms in focal states

    (e.g., Fire at Church (NC), Lightning Damage NC)
- Driving and Student Question Board
- Lightning Effects Board
- Lesson 1 Power point

**Per Student:**

**Student Handout**

## Timing and sequence

| Est. Time (min.) | Activity | Setting |
|---|---|---|

| | | |
|---|---|---|
| 20 | **1.1 Introducing Lightning (Part I)** | Whole class and small groups |
| 25 | **1.2 Obtaining Information about Prevalence of Lightning (Part I)** | Whole class and small groups |
| 10 | **1.3 Introducing the unit driving questions with the focus on the effects on lightning (Part I)** | Small groups |
| 25 | **1.4 Generating of student questions (Part I)** | Small groups and Whole Class |
| 45 | **1.5 Exploring the Impacts of Lightning (Part II)** | Small groups and Whole Class |
| 10 | **1.6 Reflection and Concluding the Lesson (Part II)** | Small groups and Whole Class |

## Instructional Sequence

## Lesson 1 Part I

### 1.1 Introducing Lightning

1. Start the unit by showing students a video of a thunderstorm with prominent lightning strikes and them to take notes on Student Handout.
   - Please be mindful of the videos/instructional aid being presented to the student to avoid triggers of ill experiences that affect students' emotions in the classroom concerning the lesson.
2. Ask students to “turn and talk” with their neighbor about their observations of the video and compare it to their memories of a personal experience with lightning.
3. Given that it is impossible to create real lighting in the classroom, invite students to think that whether very small examples of lightning can be created in a classroom environment.
4. After students share their ideas, make a demo experiment in dark classroom to show small sparks (like a very little lightning) by using a Van de Graaff Generator.

### Van de Graaff Generator Experiment

- Safety Precautions: Ensure that the large sphere is connected to the earth/grounded after use either by using a wire or the small sphere. The current produced by the machine causes problems with people with heart problems or pacemakers. Warn the students to be aware of the small shocks they will experience during the experiment.
- Material: A Van de Graaff Generator
- **C**reating Sparks

- Begin by touching the smaller sphere, which is connected to the grounding wire, to the large dome.
- Turn the knob to the left (counterclockwise).
- Switch on the Van de Graaff generator.
- Gradually turn the knob to the right (clockwise) to start the motor, which will move the belt.
- Once the charge has built up on the dome, carefully move the small sphere away. Ask a student to dim the lights so the sparks are easier to see.
- Move the small sphere around the dome in various positions to display the sparks to everyone.

The introduction should happen with the whole group of students together. The teacher should ensure that every student participates by using the method of "**talking** stick" or setting timed turns. The time allotted for his session should be 25mins.

**1.2 Obtaining Information about Prevalence of Lightning**

5. Prompt students to share whether lightning is common in the area where they live.
   After students share their thoughts, provide data showing the frequency of lightning in the USA, particularly in Alabama and North Carolina or any other focal state by using the Interactive Lightning Report 2023.
6. Facilitate a whole class discussion where students share their interpretations of the report about lightning in the USA (e.g., lightning frequency is changing among states, and they live in one of the top states).
7. Use the following report as a specific reference to North Carolina and Alabama for student analysis.
   - Number of lightning Strikes by States
   - Lightning Counts by States
   - Dangerous Thunderstorm Alerts by Top 10 States
   - Thunder Hours by Top 10 States

**1.3 Introducing the Unit Driving Question with a focus on the Effect of Lightning**

8. Draw students' attention to the effect of lightning by using questions, recent event in your region and consider showing some news about the effect of lightning (e.g., Fire at Church (NC), Lightning Damage NC).
   - ➢ Please be mindful of the videos/instructional aid being presented to the student to avoid triggers of ill experiences that affect students' emotions in the classroom concerning the lesson.
9. Facilitate a brief whole-class discussion where students share about the impact of lightning

in their area.

10. Building on class discussions, the teacher introduces **the driving questions of the unit: "How does lightning impact people and the environment where I live? What can we learn about lightning from the effects?**

### 1.4 Generation of Student Questions

11. Guide students to work in pairs or small groups and support students in generating questions using questions formulation technique to generate questions about what they need to figure out to address the unit driving question (e.g., questions about the causes, characteristics of lightning, how and why it occurs, and effects of lightning strikes, lighting protection).
12. Give each group post-it notes and or provide an online platform for taking notes and ask them to write one question on each (the top three they came up with).
13. Ask students to categorize their questions in small groups based on the question topics (student groups will generate their own topics).
14. Bring the class back together to share some of their questions. Support students in summarizing the categories to have 5-6 class categories on the board (based on student's questions and the categories they came up with in small groups). Students should post their questions in the room on the Driving Question board (or an online Driving Question Board) based on the categories (ex. All questions related to designing a solution in one area, questions related to lightning safety in another, questions related to electrostatic force in a third).
15. Ask students to reflect on how these questions will help in answering the driving question. Emphasize that the class will return to these questions periodically throughout the unit.

**Supporting student discussions**

Use **productive discussion talk moves** to support small group and large groups discussions that can help members of the class (the teacher and students) in listen to each other carefully, deepen their reasoning and think and figure out together.

## Lesson 1 Part II

### 1.5 Exploring the Impacts of Lightning

16. Use one of the student-generated questions or their initial discussion about the effects of lighting to lead students' focus on the impact of lightning.

17. Introduce the **lesson guiding questions: How does lightning impact people, and the environment where I live? 2. What can we learn about lightning from these effects?**
18. Guide students to work in pairs/small groups to address these questions.
19. Students share their experiences, observations, and any stories they have heard about the impacts of lightning on people, animals, the environment, and structures as well as they discuss their predictions for how and why lightning might cause these impacts (cause-and-effect relationship, e.g., if lightning causes fires, this might be because of lightning being too hot.)
20. Give each pair/group post-it notes and ask them to write one impact of the lightning on each as well as predicting the characteristics of lightning based on that impact.
21. Students post their notes for the impacts of lightning and predicted characteristics of lightning on a board in the room, or an online platform accessible to whole class.
22. Facilitate a whole class discussion where students discuss the impacts of lightning and the underlying potential cause-and-effect relationships with an emphasis on what these impacts reveal about the nature or characteristics of lightning. (What can we learn about lightning from these effects?)
23. During the discussion, ask students to group the impacts of lightning and predictions about the nature or characteristics of lightning by using either post-it notes on class board or online platform.
24. Building on the class discussion, invite students to combine the information they had about the impacts of lightning with the additional data presented in the reports.
25. Provide data about the impacts of lightning for students to examine:
    - If available, provide tech tools for students' search (computer, tablet to search for effects of lightning (suggest links to specific web pages) OR
    - provide data sheets, reports about the impact of lightning strikes) (Strikes Report 2002)
26. In pairs or small groups, students examine additional data (including both positive and negative impacts) by focusing on the cause-and-effect relationship of how and why lightning might cause these impacts.
27. Facilitate a whole class discussion where students share and discuss the new information they learn about the various effects of lightning and the hazards it poses and their predictions about the potential cause and effect relationship (characteristics of lightning).
28. Give each pair post-it notes and ask them to write one effect on each or add a note to online platform.
29. Students should add their new post-it notes to the board / online platform and create new categories as necessary

- ★ In addition to the direct impact of lightning such as fires, damage to buildings, people or animal inquiry, students could consider the cost of lightning damages (insurance, repairs and businesses suffer, energy shortage, etc.) or teacher might guide them to think about these kinds of secondary impacts that affect them or their community.

**1.6 Reflection and Concluding the Lesson**

30. Encourage students to revisit the lesson level and unit driving questions share what they have learned and what they are curious about moving forward.
31. Any complete activity and questions answered from the driving question board should be physically moved to the activity summary board (ASB) alongside a short description about the "big ideas" students figured out.
32. Ask students to reflect on their questions and revise or add new questions to address the unit driving question. These new questions get added to the driving question board (DQB).
33. Encourage students to learn more about the impacts of lightning as they collaborate with people from their family or community.

Transition to next lesson

34. Introduce the focus on next lesson by building on the student generated questions: Why is lightning so dangerous? How and why does lightning lead to these effects or hazards? *How does understanding how lightning occurs help protect us and my community?

**Assessing Student Artifacts**

- Look at student generated questions to assess the use of open-ended, testable questions including variables addressing the unit driving question.
- Look at student notes about the impacts of lightning and predictions for the nature of lightning to assess the use of cause and effect when describing interactions between lightning and the environment and nature and or characteristics of lightning.

Name: _____ Date: _____

Class: _____

**Unit 4: Static Electricity and Lightning**

**Post Unit Assessment**

## Improving Protection via Lightning Rods

### Introduction

A community in the south has experienced several lightning storms that caused severe damage to various structures including houses, water towers, schools, and power lines. Several issues reported about the lightning rods which were installed in structures to mitigate hazards of the lighting and protect people, animals, and structures. In this task, you will help the members of the community in improving lightning protection via lightning rods in their area.

### Part 1: Placement of Lightning Rods

In a neighborhood, a lightning rod was installed on the local school. However, while multiple nearby buildings were struck by lightning and damaged, the lightning rod installed at the local school was not struck by lightning. Citizens had challenges to understand why it happened and asked for your help to understand the case and identify the best place for a lightning rod in the neighborhood.

Table 1. Information about the buildings in the focal neighborhood

| Structure Name | Height (m) | Roof Material | Conductivity of Roof Material |
|---|---|---|---|
| Local School (Lightning Rod) | 8 | Flat Roof (Asphalt) | Low |
| Community Center | 15 | Metal (Aluminum) | Moderate |
| Water Tower | 25 | Metal (Steel) | High |
| Power Substation | 20 | Concrete | Extremely low |

1. Use the information given in Table 1 and your understanding of interactions between distance objects due to electrostatic forces and formation of lightning to explain why nearby buildings were struck by lightning while the local school's lightning rod was not.

Your explanation should incorporate:

- ❑ An application of Coulomb's Law for describing factors affecting the strength of electrostatic forces
- ❑ A comparison of the building from Table 1 based on their related features,
- ❑ A clear reasoning based on scientific principles related to electrostatic forces and electrical discharge justifying your explanation of why the local school was not struck by lightning, but other buildings did.

2. Based on your analysis of the buildings in the focal neighborhood (Table 1), suggest the best building for installing a new lightning rod in the neighborhood. Explain your reasoning clearly so residents can understand the justification for your suggestion.

Your explanation should incorporate:

- ❑ An application of Coulomb's Law for describing factors affecting the strength of electrostatic forces,
- ❑ A comparison of the buildings based on their related features for being a best location for lightning rod,
- ❑ A clear reasoning based on scientific principles related to electrostatic forces, electrical discharge, the function of a lightning rod justifying your explanation of why the lighting rod should be installed to the certain building.