LESSON OVERVIEW:
Agriculture is highly dependent on the weather. Ever since the first seed was sown, farmers have watched the sky and hoped for good weather. Many things we depend on to survive – the food we eat, the clothes we wear and the shelters we live in – are products of agriculture, and their production can be affected by the weather. Therefore, it is important to study, monitor and forecast the weather.

ESSENTIAL QUESTION:
How do temperature, moisture and pressure changes affect weather?

TOPICAL ESSENTIAL QUESTION:
What factors are instrumental in the formation of rain?

LESSON OBJECTIVES:
Students will be able to:
1. Model cloud formation by altering atmospheric conditions.
2. Construct a thermometer and measure temperature.
3. Develop an understanding of the effect of heat on the volume of liquids.
STANDARDS:

Middle School
MS-ESS2-4
Students who demonstrate understanding will be able to:
Develop a model to describe the cycling of water through Earth’s systems, driven by energy from the sun and the force of gravity.

MS-ESS2-5
Students who demonstrate understanding will be able to:
Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.

MS-ESS2-6
Students who demonstrate understanding will be able to:
Develop and use a model to describe how unequal heating and rotation of the Earth causes patterns of atmospheric and oceanic circulation that determine regional climates.

High School
HS-ESS2-4
Students who demonstrate understanding will be able to:
Analyze and interpret data to explore how variations in the flow of energy into and out of Earth’s systems result in changes in atmosphere and climate.

Science and Engineering Practices:
1. Asking questions
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations and designing solutions
7. Engaging in argument from evidence
8. Obtaining, evaluating and communicating

Crosscutting Concepts:
1. Patterns
2. Cause and Effect: Mechanisms and explanations
3. Scale, Proportion and Quantity
4. Systems and System Models
5. Energy and Matter: Flows, cycles and conservation
6. Structure and Function
7. Stability and Change

45 min. class time

MATERIALS PER GROUP:

Cloud in a Bottle:
• One 1 liter plastic bottle with cap
• Foot pump with rubber stopper attached
• Water
• Rubbing alcohol
• Aquarium liquid crystal thermometer
• Pipette
Make Your Own Thermometer:

- Glass test tube
- Rubbing alcohol, 91%
- Red food coloring
- Two 8 oz. disposable water bottles*
  *A beaker or plastic cup can be used in place of water bottles (as long as it will hold the glass test tube in an upright position)
- Parafilm*
  *Modeling clay can be substituted if parafilm is not available. Mold the clay around the disposable pipette and the opening of the test tube (see image 1).
- Disposable pipette*
  *The best option is to drill a hole through a rubber stopper and insert rigid plastic tubing through to create a permanent “thermometer” (see image 2).
- Hot water (near boiling)
- Ice water
- Funnel

LAB BACKGROUND INFORMATION:

NOTE: This is background information for the teacher to assist in facilitating learning and will be explained to the students after the Explore section.

Agriculture is highly dependent on the weather. Ever since the first seed was sown, farmers have watched the sky and hoped for good weather. Snows in the winter keep the soil moist; rains in the spring germinate seeds and provide vigorous growth; sun and frequent showers in the summer provide energy for seed and robust stalks; dry fall days allow for harvest and freedom from damaging winds and hail – farmers constantly monitor the weather.

Many things we depend on to survive – the food we eat, the clothes we wear and the shelters we live in – are products of agriculture, and their production can be affected by the weather. Therefore, it is important to study, monitor and forecast the weather.

Weather refers to the state of the atmosphere at a specific time and place. It describes conditions such as temperature, atmospheric pressure and dew point.

Temperature is a measure of the average kinetic energy (motion) of molecules. When the temperature is high, molecules in the air move rapidly. When the temperature is low, molecules in the air move slowly.
Anemometers are used to measure air temperature in degrees Fahrenheit (°F), Celsius (°C) or both.

Temperature plays an important role in everyday life. It helps us determine what to wear and what outdoor activities we can participate in. In agriculture, temperatures affect planting dates and the growth of plants, as well as insects and crop diseases. It also affects soil temperature and moisture content. Freezing temperatures in the fall generally mark the end of the growing season.

**Atmospheric pressure** determines the types of weather that are likely to occur. The types of weather affect the kind of field work that can be done and influence the effectiveness of herbicide and pesticide treatments.

Air pressure and temperature play an important role in cloud formation. A cloud is a visible mass of condensed water vapor suspended in the atmosphere. Clouds are very important because they produce rain to water plants and crops. Clouds also shade the earth, affecting air, soil and water temperatures. As the sun warms the ground, water evaporates, changing from a liquid to a gas (water vapor). Water vapor is suspended in the air above the ground; the amount can be measured and is known as **humidity**.

As the sun warms the air above the ground, the air expands and becomes less dense; expanding air has low atmospheric pressure and rises. As the warm air continues to rise, it starts to cool. This causes the water vapor to condense on microscopic dust particles (called **condensation nuclei** and change from a gaseous state back into a visible, liquid state known as a cloud (Figure 1). Stormy and cloudy weather is associated with low pressure.

Cooler air is denser and sinks because air molecules pack more closely together, leaving less room to move. Cool weather has low atmospheric pressure. Fair weather is usually associated with high pressure.

Knowing the air pressure can help predict weather patterns. People, such as **meteorologists**, can measure air pressure in the atmosphere with an instrument called a barometer. The units of measurement for barometers are commonly in millibars (mb) or inches in mercury (inHg).

The formation of liquid water from water vapor is called **condensation**. The air is saturated when there is enough water vapor in the air for condensation to occur.
ENGAGE:

Ask students to explain:
1. What are clouds?
   Clouds are water vapor that has cooled and condensed onto dust particles in the atmosphere.
2. What causes clouds to form?
   As the warm air rises from the surface of Earth, it cools. Cool air cannot hold as much water as warm air and so as the air cools the water vapor will condense onto dust particles in the atmosphere. When millions of dust particles come together, they create a visible cloud.
3. What causes rain to fall from the clouds?
   Rain occurs when the air becomes saturated and cannot hold any more water.

Introduction
In this activity, you will conduct hands-on activities to improve your understanding of weather and factors that influence it.

EXPLORE:

Prior to lab, teachers need to:
1. Prepare the alcohol by placing several drops of red food coloring into the bottle of rubbing alcohol and mixing.
2. Cut the bulbs off the top of the pipette and the pointed end of the pipette so all you have left is a plastic tube.
3. Cut pieces of parafilm for each group of students.
   Note: Students often have difficulty getting the parafilm onto the test tube without tearing it, so the teacher should be prepared to help students with this step.
4. If using liquid crystal thermometers for cloud formation, apply to sides of bottles.

PROCEDURE:

Activity 1: The Ups and Downs of Thermometers
1. Carefully pour the colored alcohol into the test tube until the tube is almost completely full.
2. With the help of a partner, stretch a small piece of parafilm over the top of the test tube so it is well sealed.
3. While holding the parafilm tight with one hand and the pipette with the other, carefully pierce through the plastic so the pipette goes into the alcohol. About 3-4 centimeters of pipette should stick out of the top of the plastic. This is a thermometer.
4. Using the funnel, pour hot water into one water bottle until it is about two-thirds full. Caution: the water is very hot!
5. Pour ice water into the other water bottle until it is two-thirds full.
6. Carefully lower the tube into the hot water, and observe what happens to the alcohol in the plastic tube.
7. Transfer the thermometer to the ice water. Watch your thermometer for about one minute, and observe what happens to the level of the alcohol.
Activity 2: Cloud in a Bottle
1. Pipette 5 mL of rubbing alcohol into the 1 liter bottle.
2. Swirl the alcohol around in the bottle; make sure to coat the sides.
3. Place the rubber stopper from foot pump in the mouth of the bottle.
4. While holding the stopper in place tightly, pump the foot pump one time.
5. Record the pressure and temperature in the data table. Pull the stopper out; closely observe what happens, then write down your observations in the data table. Note if there is any change in temperature.
6. Repeat the above step, but this time, pump the foot pump two times.
7. Record the pressure in the data table. Remove the stopper while carefully observing; write your observations in the data table. Note if there is any change in temperature.
8. Repeat this procedure four times, increasing the pumps by one (1) each time. Continue recording the pressure and your observations in the data table. Note if there is any change in temperature.

Table 1: Cloud in a Bottle Data Table

<table>
<thead>
<tr>
<th>Number of Pumps</th>
<th>Pressure in PSI</th>
<th>Temperature of Bottle</th>
<th>Observations</th>
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Note to the Teacher: In this experiment, temperature and pressure have a direct relationship. As pressure increases inside the bottle, so does the temperature. When the pump stopper is removed from the bottle top, there is a dramatic decrease in pressure and temperature which causes the water vapor to condense onto any dust particles that are in the bottle, thus forming a cloud.

EXPLAIN:

The Lab Background Information from the Teacher Guide is repeated in the Explain section of the Student Guide.
EVALUATE:

1. What are the microscopic dust particles that water vapor attaches to during condensation called?
   A. Evaporation nuclei  
   B. Condensation nuclei  
   C. Clouds  
   D. Rain

2. Temperature is a measure of the average amount of motion of molecules.
   A. True  
   B. False

3. When there is enough water vapor in the air for condensation to occur, the air is:
   A. Saturated  
   B. Pressurized  
   C. Condensed  
   D. Precipitating

4. Weather refers to the state of the atmosphere at a specific time and place.
   A. True  
   B. False

5. Briefly describe how clouds form.
   As the sun warms the air, the air expands, becomes less dense and rises. As the warm air continues to rise, it cools and condenses on condensation nuclei. The water then changes back into a liquid, forming a cloud.

6. Why did the red alcohol move up in the plastic tube when your thermometer was placed in hot water?
   As the air in the tube warms, it expands, forcing the alcohol up the tube. When the air cools, the pressure decreases and the alcohol flows back down the tube.

7. Explain why weather is important to agriculture.
   The products of agriculture depend upon moisture, temperature and sunlight (all components of weather).

8. Why are low pressure areas associated with precipitation and high pressure areas associated with clear, sunny days?
   With low pressure systems, the water vapor in the air rises, starts to cool and forms clouds. With high pressure systems, the water vapor is pushed down to Earth's surface, so no clouds and high humidity.

9. Look at the two maps below. The first map shows the atmospheric pressure for North America on Sept. 19, 2015. The second map is a satellite image showing the cloud cover (water vapor) in the atmosphere on Sept. 19, 2015.
   As you compare the two maps, what patterns do you see? Please provide evidence to support your answer.
   Clouds form along the low pressure areas as indicated by the cloud cover areas on the map.
What is the relationship between pressure and cloud cover? Please explain your answer.

The areas that have high pressure are areas of fair weather and do not have cloud cover due to warmer temperatures. The cloud formation is along the low pressure lines, which indicates cooler temperatures.

Figure 1.

(Retrieved from NOAA.gov on Sept. 19, 2015.)

Figure 2.

LET’S TALK ABOUT THE WEATHER

LESSON OVERVIEW:
Agriculture is highly dependent on the weather. Ever since the first seed was sown, farmers have watched the sky and hoped for good weather. Many things we depend on to survive – the food we eat, the clothes we wear and the shelters we live in – are products of agriculture, and their production can be affected by the weather. Therefore, it is important to study, monitor and forecast the weather.

ESSENTIAL QUESTION:
How do temperature, moisture and pressure changes affect weather?

TOPICAL ESSENTIAL QUESTION:
What factors are instrumental in the formation of rain?

LESSON OBJECTIVES:
You will be able to:
1. Model cloud formation by altering atmospheric conditions.
2. Construct a thermometer and measure temperature.
3. Develop an understanding of the effect of heat on the volume of liquids.

KEY VOCABULARY:
- Weather
- Condensation
- Temperature
- Meteorology
- Atmospheric pressure
- Condensation nuclei
- Atmosphere
- Humidity

SAFETY PRECAUTIONS:
- Do not eat or drink in the laboratory.
- Wear safety glasses and lab coat when performing the experiments.
- Use caution when handling the glass test tubes.
- Use extreme caution when pouring hot water.

TOTAL DURATION:
15 min. pre-lab prep time; 45 min. class time
MATERIALS PER GROUP:

Cloud in a Bottle:
- One 1 liter plastic bottle with cap
- Foot pump with rubber stopper attached
- Water
- Rubbing alcohol
- Aquarium liquid crystal thermometer
- Pipette

Make Your Own Thermometer:
- Glass test tube
- Rubbing alcohol, 91%
- Red food coloring
- Two 8 oz. disposable water bottles*
  *A beaker or plastic cup can be used in place of water bottles (as long as it will hold the glass test tube in an upright position)
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ENGAGE:

1. What are clouds?
2. What causes clouds to form?
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3. What causes rain to fall from the clouds?
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INTRODUCTION:
In this activity, you will conduct hands-on activities to improve your understanding of weather and factors that influence it.

EXPLORE:
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**EXPLAIN:**

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EVALUATE:

Name: ______________________________________________________

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   B. Condensation nuclei
   C. Clouds
   D. Rain

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   A. True
   B. False

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