LESSON: Forecasting an Eruption

Grade Range	6th - 8th
Target Grade	7th
Duration	20-30 min each (2 hours total)
Location	Online

Objectives:

Forecasting an Eruption is designed as a 4-part online activity where students will:

- Understand that volcanoes are complex and that there is no one thing that tells us everything we need to know about a volcano's behavior;
- Interpret how patterns and changes they observe through different types of monitoring data relate to patterns and changes in the volcanic system;
- Forecast future volcanic behavior using different types of monitoring data as their basis for evidence;
- Understand the real-world importance of monitoring volcanoes and communicating their observations and interpretations (setting the alert level and informing the public).

Learning Experience:

These lessons require internet access. In the first three lessons, students will be trained on three different ways of monitoring volcanoes: deformation, gas emissions, and seismicity. In the final lesson, students will observe and interpret patterns and changes in a volcano's shape, gas emissions, and seismic activity and use their interpretations to forecast volcanic activity!

The first three lessons may be completed in any order, as they independently train students on three types of volcanic monitoring techniques. The fourth lesson (Forecasting an Eruption), requires students to synthesize the knowledge they gained about these three monitoring techniques in order to forecast volcanic activity; the fourth lesson should be used only after the first three are completed.

Materials:

- Internet access
- Paper
- Pencil

Next Generation Science Standards:

Dimension from Framework	Connections to the 3 Dimensions
Science and Engineering Practice: • **Analyze and Interpret Data**	Students will interpret data in all activities. In the final activity, "Forecasting An Eruption," students will **interpret** several types of contemporaneous **monitoring data**. Based on

• **Engage in an Argument from Evidence**	their interpretations, they will "set the hazard level" based on their interpretations. Setting the hazard level is a way of **engaging in an argument from evidence** that real scientists do!
Disciplinary Core Ideas: • **ESS3:B** Natural Hazards	Humans cannot control volcanoes and the **hazards** they pose, but they can keep a close watch on a volcano through volcanic monitoring. Should activity at a volcano increase and pose danger to those living in its shadow, scientists can use their knowledge to inform decision-makers. In doing so, they can help prevent a volcanic eruption from becoming a volcanic disaster.
Crosscutting Concepts: • Observing Patterns • Stability and Change	Volcanoes are dynamic systems. **Patterns** and **changes** observed using volcanic monitoring can be reflective of important **changes** happening within a volcano. In these activities, students are presented with realistic data sets and are given the tools and knowledge they need in order to interpret the meaning of patterns and changes in a volcanic system, just as real scientists do!

Common Core State Standards:

Common Core State Standard (CCSS)	Connections to CCSS
ELA	WHST.6-8.1 Write arguments focused on discipline content
Math	

Background:

Volcanoes are very complex, and there is no one thing that tells us everything we need to know about a volcano's behavior.

Challenge:

Students are given the role of "trainee" working with members of the volcano monitoring team from the USGS Cascades Volcano Observatory. Their job is to learn about different ways of volcano monitoring: **volcano deformation, earthquakes (seismicity), and gas emissions** and what these different monitoring techniques can tell us about activity at a volcano. Each of these techniques can each provide important information that sometimes can be an important indication of an approaching eruption. In the fourth and final activity, "Forecasting an Eruption," students will integrate the knowledge they acquire in the first three activities (**volcano deformation, earthquakes (seismicity), and gas emissions**) about what we can learn from these different monitoring techniques to set the appropriate Alert Level and communicate their findings to the public.

Answer Key:

VOLCANO DEFORMATION

1. **What did you find most interesting about the video?**
   The topics described in the video indicate that moving magma tends to deform the surface of the Earth, where the ground can bulge upwards or spread apart. The video also describes how deformation of the ground is measured by measuring changes in tilt (using tiltmeters) or seeing points on the ground that move away from each other (using Global Positioning System (GPS)).

2. **Describe in your own words what is happening in Figure 1 below.**
   The orange represents magma moving underground; the upward motion of magma is represented with the red arrow. The upward motion of magma makes the ground move upward and outward, represented by the white arrows. This motion of the ground is deformation.

3. **Choose one of the techniques that scientists use to measure deformation described above (GPS, tilt, or EDM). In your own words, explain how the technique you selected is used to measure volcano deformation.**
   See the descriptions in the activity itself:

Name	How equipment works	How deformation is measured

Global Positioning System (GPS)	GPS devices commonly found in cell phones and in cars are used to find someone's location and provide directions. Similarly, scientists can use GPS to precisely measure changes in the position of a GPS receiver. GPS devices work by receiving signals from a network of GPS satellites, which are constantly orbiting the planet. These satellites transmit information about the satellite's position at an exact time. If a GPS device receives this information from at least four satellites, it is able to determine the distance and angle to each satellite and precisely calculate its position on the surface of the earth.	Scientists use GPS to precisely measure changes in the position of fixed points on the ground surface and reveal the rate and direction in which the deformation is occurring.
Tiltmeter	A tiltmeter is similar to a level used for carpentry, with a small device filled with fluid and a bubble. The bubble is in the center when it is level and moves when it is tilted. By filling the tiltmeter with a fluid that conducts electricity and placing electrodes along the length of the tiltmeter, the tiltmeter generates an electrical signal that corresponds with the direction and degree of tilt.	The voltage of the electric signal depends on the angle of the tiltmeter. By measuring the voltage of the tiltmeter, scientists are able to know the angle and degree to which the ground surface is tilting.
Electronic Distance Meter (EDM)	A reflective device (a mirror) is placed on the ground surface of the volcano. Far away, an EDM is pointed towards that reflective device. The EDM shines a laser, the light is bounced back by the reflector, and the EDM receives the the light.	By calculating the amount of time it takes for the laser beam to return to the EDM, scientists are able to calculate the distance between the EDM and the reflector. If this distance changes, deformation is happening!

4. **What is the measured tilt (in degrees) in Figure 7? Remember that tilt is measured by measuring the different between the sensor and the horizon (which is used as a reference point).**

   -10 degrees

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5. **What I s the measured tilt (in degrees) in Figure 8?**

   10 degrees

6. **Which Figure (7 or 8) shows a bulge (swelling of the ground surface; this is called inflation) compared to Figure 6?**
   Figure 8 shows a bulge, or inflation of the ground surface. (Figure 7 shows deflation of the ground surface).

7. **Describe the pattern that you see in the graph of Figure 10. Does the line get steeper or less steep before an eruption?**

   The lines get progressively steeper as each eruption approaches.

8. **Does the steepness of the tilt measurement graph in Figure 12 change? If so, when does it get the steepest?**
   Yes, the steepness (or slope) of the tilt measurement increases at later dates. The slope of the graph sharply increases mid-March, 1982.

9. **Based on the tilt measurement data, do you think it is likely that an eruption might occur in late March? Explain why or why not.**
   Yes, it is likely that an eruption may occur in late March. The slope of the graph increases, which serves as evidence for magma moving upwards. The increase in slope could be due to the increased volume of magma that has moved upwards or could be due to the magma getting shallower.

VOLCANIC GAS EMISSIONS

1. **In your own words, describe how gas can create explosive eruptions.**
   Magma contains gases. Sometimes these gases can escape from a volcano, but sometimes these gases remain in the magma and become pressurized. If the gas pressure is high enough (or if something happens to release the pressure, like a landslide), the gas pressure can release suddenly, creating a volcanic explosion.

2. **In your own words, describe what is happening in Figure 2a, 2b, and 2c below. If you need help, watch the video again.**
   2a: Magma is rising and gases are beginning to come out of the magma.
   2b: Magma continues to rise closer to the surface. When this happens, pressure decreases and gas comes out of solution rapidly.
   2c: An eruption is underway! The rapid expansion of gases created an explosive eruption.

3. **What did you find most interesting about the video?**
   This video described why monitoring volcanic gases is exciting and important, how gas emissions are monitored using a spectrometer on a plane, and how dissolved gases can create an explosive eruption.

4. **In your own words, explain why it is important to monitor gases on a routine basis at active volcanoes like Mount St. Helens.**
   At any time, changes can happen at volcano that could increase or decrease its likelihood to erupt. Watching the gas emissions from volcanoes like Mount St. Helens can reveal an increase or decrease in the probability of an eruption occurring.

5. **Which of the following do you think could be the cause of an increase in gas flux at a volcano? Mark all that apply.**
   a, c, and f

6. **Use Figure 3 to describe the overall pattern of sulfur dioxide flux emissions between 1980 and 1988. In other words, did the sulfur dioxide flux increase or decrease (or both) through time?**
   Between 1980 and 1988, sulfur dioxide flux decreased overall from ~3000 tonnes/day to less than 500 tonnes/day.

7. **Are there any deviations from the overall pattern in the sulfur dioxide flux from 1980 to 1988? In other words, were there any sudden increases or decreases in sulfur dioxide flux that don't match the overall pattern? If so, when did they happen?**
   Yes, there are deviations from the overall pattern of decreasing gas flux between 1980 and 1988. Sometimes gas increased rapidly, represented by the sharp peaks in the Mount St. Helens Emissions graph. These occurred early to mid-1982, mid to late- 1984, early 1986 and late 1986.

8. **Use Figure 4 to describe the pattern of sulfur dioxide flux in 1982.**
   In 1982, the sulfur dioxide flux was generally low (less than 200 tonnes/day). The gas emissions increased in late March to greater than 600 tonnes/day, decreased, then increased sharply to greater than 1800 tonnes/day in late May. After late May, the sulfur dioxide flux decreased to 600 tonnes/day or less.

9. **What do you think is the relationship between the pattern of sulfur dioxide flux in 1982 and changes in the status of the magma beneath the volcano during this time? Explain why you think so.**
   There are several possible reasons for the increases in gas flux observed in 1982. It could have been that magma was entering the volcano more quickly than it was before, that magma was moving closer to the surface, or that the new magma that was entering the volcano had significantly more dissolved gas than before. All are justifiable reasons. To be sure, gas emissions monitoring data would need to be observed alongside other types of monitoring data, like seismicity.

VOLCANO SEISMICITY

1. **The job of the seismic network at Mount St. Helens is to detect all of the possible signs that might be pointing towards what?**

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It detects signs that might show that magma is moving towards the surface and getting close to eruption.

2. **What did you find most interesting about the video?**
The video describes how the USGS mitigates the effects of hazards by providing warning to those living near volcanoes that might be impacted by an eruption. It also describes how moving magma can create earthquakes, detected by the seismic network. A seismic network typically consists of about 1 – 20 sensors and that it is better to have more sensors because it increases scientists' ability to interpret the seismic signals. These sensors are connected to a radio network that sends the signals back to the scientists. Finally, the video briefly describes that working at an observatory is exciting because there are many people with different specialties that work together with their different expertise to watch volcanoes.

3. **Is shallow or deep seismicity more likely to indicate an approaching eruption?**
Shallow seismicity is more likely to indicate an approaching eruption than deep seismicity.

4. **Do all earthquakes in volcanic areas indicate an approaching eruption? Explain why or why not.**
No, not all earthquakes in volcanic areas indicate an approaching eruption. Earthquakes can be made in different ways. Examples of earthquakes at volcanic areas that do not indicate an approaching eruption include earthquakes from moving animals, helicopter vibrations, and tectonic earthquakes.

5. **Describe the pattern of seismicity observed in 1982. Were the earthquakes shallow, deep, or a combination of both? Were there more or less earthquakes as compared with the previous year (1981)?**
In 1982, there was a mix of shallow and deep earthquakes. However, there were more shallow earthquakes than deep ones. Overall, there were slightly more earthquakes in 1982 compared to the previous year (1981).

6. **What is the main difference in the pattern of seismicity observed in 1988 as compared with what you observed in 1982? In your answer, include whether the amount of earthquakes increased or decreased and whether those earthquakes were deep, shallow, or both.**
The main difference in seismicity during 1982 and 1988 is the depth of the earthquakes. In 1988, there were many more deep earthquakes than shallow earthquakes. In 1982, there were more shallow earthquakes than deep earthquakes.

7. **What, according to the report, did scientists think was the reason for the increase in deep seismicity?**
According to the report, the increased number of earthquakes was due to the "replenishment of the magma reservoir, a body whose top is thought to lie ~7 km below the crater." In other words, new magma was entering the volcano at a depth of about 7 km.

8. **What, according to the report, would have greatly increased the scientists' concern?**
   An increase in shallow seismicity would have greatly increased the scientists' concern.

9. **Do you think the seismic activity observed in 2004 was a sign that Mount St. Helens would erupt? Justify your answer using the patterns you see in the seismic data.**
   The seismic activity in 2004 was a sign that Mount St. Helens was likely to erupt. This is evidence by the depth of the seismicity. Most of the earthquakes in 2004 were shallow (less than 3 km). The shallow earthquakes showed that magma was moving close to the surface, and therefore the volcano had an increased chance of erupting.

10. **What happened on October 1, 2004?**
    There was a steam and ash explosion at Mount St. Helens, sending ash and water vapor several thousand feet into the air. This was the beginning of a new phase of eruptive activity at Mount St. Helens that continued for over 3 years. This eruption fracture Crater Glacier.

FORECASTING AN ERUPTION

1. **For both Scenarios 1 and 2, choose which statement best describes the seismicity from the options below.**
   Scenario 1-Seismicity at the volcano is at an elevated level, with **many deep** earthquakes
   Scenario 2- Seismicity at the volcano is at an elevated level, with **many shallow** earthquakes

2. **For both Scenarios 1 and 2, choose which statement best describes the deformation from the options below.**
   Scenario 1-Deformation at the volcano is at a low level, with a **gradual increase** in tilt.
   Scenario 2- Deformation at the volcano is at a low level, with a **rapid increase** in tilt.

3. **For both Scenarios 1 and 2, choose which statement best describes the sulfur dioxide emissions from the options below.**
   Scenario 1- SO_2 measurements indicate a **low** level of gas flux.
   Scenario 2- SO_2 measurements indicate as **elevated** level of gas flux.

4. **Which of the two time periods (Scenario 1 or 2) shows more signs of approaching eruptive activity? Justify your answer using information from the seismicity, deformation, and gas monitoring graphs.**
   Scenario 2 shows more signs of approaching eruptive activity. The combination of shallow earthquakes and rapid increase in tilt indicate that magma is moving close to the ground surface. The high level of sulfur dioxide flux also potentially shows that magma is close to the ground surface, but also that there is a lot of gas in the magma. Dissolved gases in magma created volcanic eruptions.

5. **What is the current Alert Level at Mount St. Helens?**

This is subject to change at an active volcano like Mount St. Helens, but at the time of writing, the Alert Level is Normal.

6. **Find a volcano that is not currently at the normal level. List the name, Alert Level, and color code of this volcano.**
   This is highly variable. Check the U.S. Volcanoes and Current Activity Levels website for current levels.

7. **What Volcano Alert Level would you recommend assigning to the volcano for a) Scenario 1 and b) Scenario 2? Justify your choice for the Alert Level for both using what you know about the monitoring data.**
   *This (to a degree) is subject to opinion. In assessing your students' work, I would focus on their justification of their choice.
   Scenario 1- ADVISORY The volcano is showing signs of unrest (most noticeably in the increase in tilt). However, the earthquakes remain deep so the potential for eruption is still relatively low.

   Scenario 2-WATCH The volcano is showing signs of unrest, evidenced by the seismicity, deformation, and gas emissions. Monitoring data shows that magma is close to the ground surface, showing an increased potential of eruption.

8. **Using what you learned in the slideshows above, match the name of a hazard with its description of the hazard and where it affects.**

HAZARD	DESCRIPTION	WHERE IT AFFECTS
Pyroclastic flow	An extremely hot, swiftly-moving flow of volcanic ash and rock suspended in gas.	It travels in valleys but it can sometimes go up and over tall ridges.
Tephra	The general term for pieces of rock and ash blown apart by an explosive eruption.	It travels high in the atmosphere, affecting areas downwind of the volcano.
Lahar	A slurry of water mixed with volcanic ash and rocks, which is often described as having the consistency of wet cement.	It typically stays within valleys downstream of the volcano or can spread across low-lying flat areas.

9. **Find the town of Toutle, Washington. What type of types of volcanic hazards might affect the people in Toutle?**
   The map shows that the town of Toutle could be affected by lahars.

10. **What would you recommend that emergency response officials say to the people in Toutle so that they can remain safe from volcanic hazards?**
   The combination of ice/snow on the mountain and heat from the magma (especially if there is an eruption) could result in lahars that affect the people of Toutle. The people of Toutle should be aware of the areas that are at-risk from lahars and stay away from these low-lying areas.