LESSON 9: CONCEPTUALIZING MODULE II
Factors Influencing Temperature

PURPOSE/QUESTION
To understand the need to compare data sets over different parameters thus increasing the strength for students climate change positions regarding temperature.

GRADE LEVEL
9-12

TIME TO COMPLETE
1 – 50 minute time period

STANDARDS
See appendix below-page 5

LEARNING OUTCOMES

- Students will expand their knowledge base by working with their peers.
- Students will make connections between each of the lessons in Unit 1 and 2, focusing on factors that influence temperature.
- Students will see the impacts of temperature at the local, national, and global level.

STUDENT OBJECTIVES

- Use prior lessons to tie together the factors that influence temperature
- Make predictions and formulate hypotheses using evidence collected from previous lessons and by using Figures 1 and 2.
- Design a foldable demonstrating what you have learned from Units 1 and 2.

VOCABULARY

- Climate forcing
- Climate feedback
- Climate models
- Radiative forcing

TEACHER BACKGROUND

The lessons in Units 1 and 2 provide students with an introduction to data used to measure how the Earth's climate is changing and some of the factors that are causing the changes. These forays into Earth science data only scratch the surface of our accumulated evidence and knowledge. Furthermore, they are limited in the extent to which global-scale changes, long-term trends, and the full range of factors are considered. This mini lesson provides some of that broader context.

Scientists often want a single measure of surface temperature for the entire globe. To calculate this value, they average together temperature measured at stations located all over the globe. They must be careful to use stations that accurately reflect large-scale trends rather than local influences (for example, if a building was constructed right next to an observing site, it could influence the local temperature conditions). And, they must be careful to include measurements from locations all around the globe, so that the average is not biased toward one region. These and other considerations go into the calculation of the average surface temperature. However, we were unable to account for all of these subtleties in our explorations, so we will have an opportunity to examine the global average record here.

Factors that drive climate change fall into two categories: climate forcings and climate feedbacks. *Climate forcings* create an energy imbalance in the climate system, leading to warming or cooling. They can have a natural cause—such as changes in solar energy output or volcanic emissions—or be caused by human activities—such as emissions of greenhouse gases or modification of the land surface. Climate forcings are typically quantified and compared as *radiative forcings*¸ which is a measure of the change in energy flux at the top of that atmosphere resulting from the climate forcing. Radiative forcing is measured in unites of W/m^2. Lesson 3 focuses on climate forcing due to fossil fuel emissions of atmospheric CO2.

TEACHER BACKGROUND - CONTINUED

A ***climate feedback*** is a natural climate process that amplifies or dampens the response to a specific forcing. For example, when the atmosphere warms in response to CO_2 forcing, water vapor increases in the atmosphere, which amplifies the warming through the greenhouse properties of water vapor. Lesson 4 explores another feedback involving how melting ice can cause a decrease in how much sunlight is reflected back to space.

Climate models integrate everything we know about climate to simulate past conditions and to make projections about future conditions. The models have representations of the physical processes that make up climate, such as heat exchange between the oceans, atmosphere, and land; large-scale atmospheric and oceanic circulation; and elements of the water cycle. The models are driven by climate forcings. When simulating past conditions, scientists input our best estimates of past emissions, based on records of fossil fuel usage or measurements of atmospheric composition. Future simulations use various ***emissions scenarios***. Often scientists will examine one scenario in which aggressive steps are taken to curb greenhouse gas emissions and another scenario in which fossil fuel use and the resulting emissions continue to follow the business-as-usual trend.

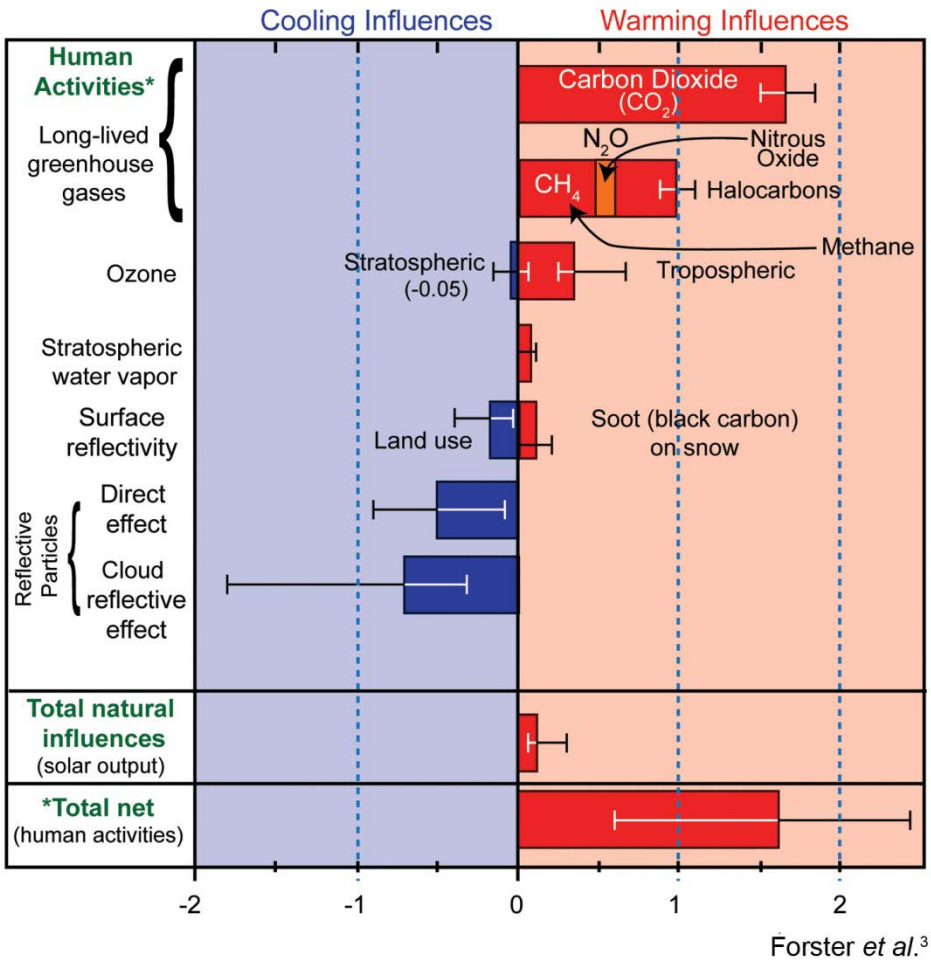

FIGURE B1

The amount of warming influence (red bars) and cooling influences (blue bars) that different factors have had on Earth's climate over the industrial age (From about 1750 to the present). Results are in W/m^2. The thin lines on each bar provide an estimate of the range of uncertainty.

SOURCE: *Global Climate Change Impacts in the United States* (2009), National Oceanic and Atmospheric Administration (NOAA).

QUESTIONS FOR MAKING CONNECTIONS

1. Carbon dioxide is just one of many climate forcings. Figure 1 show the radiative forcing associated with all major climate forcings.
    a. How much radiative forcing has been caused by CO_2 emitted to the atmosphere since 1750? How confident are scientists in this assessment?
    b. What other gases in the atmosphere have a greenhouse effect?
    c. What forcings have a cooling influence on the climate?
    d. What is the total net influence of human activities on the climate? Is there any chance that human activities could have caused cooling or even no net effect on climate? How does it compare in magnitude to the total of all natural influences?

2. In Lessons 1 and 2, we examined trends in surface temperature at specific locations and using maps that provided a snapshot of global temperature for different years. The global average surface temperature is shown in Figure 2 (black line).
    a. Estimate how much temperatures have increased since 1900 and since the 1960-1979. When has most of the warming happened since 1900?
    b. Why do think there are so many wiggles in the temperature record?

3. The right half of Figure 2 shows possible future temperature under three emissions scenarios: lower emissions, higher emissions, and even higher emissions.
    a. How much is temperature projected to rise under each scenario from 2000-2099?
    b. Compare the projected temperature changes for the 21st century to what was observed during the 20th century.
    c. What might you hypothesize about the magnitude of impacts (e.g., sea level rise, changes to ecosystems; changes in extreme weather) that these different climate scenarios might bring?

4. Scientists first raised the alarms about increasing CO_2 leading to global warming in the late 1970's. Let's consider what might have happened if CO_2 emissions were halted in 1980. For this thought experiment, we'll use the Keeling Curve from Lesson 3.
    a. Estimate what the CO_2 levels were in 1980, based on the Keeling Curve.
    b. Estimate how much CO_2 has increased from 1980 to 2010.
    c. CO_2 was approximately 290 ppm in 1750 when humans began burning lots of fossil fuels. Estimate how much CO_2 has increased from 1750 to 2010.
    d. Calculate the fraction of CO_2 that has been emitted from 1980 to 2010. This fraction roughly corresponds to the amount of radiative forcing due to CO_2 emitted during this timeframe.
    e. Do you think that stopping CO_2 emissions in 1980 could have had a significant effect on the trend in temperature over the last 30 years? Why or why not? What are some practical reasons why it is difficult to completely halt emissions?

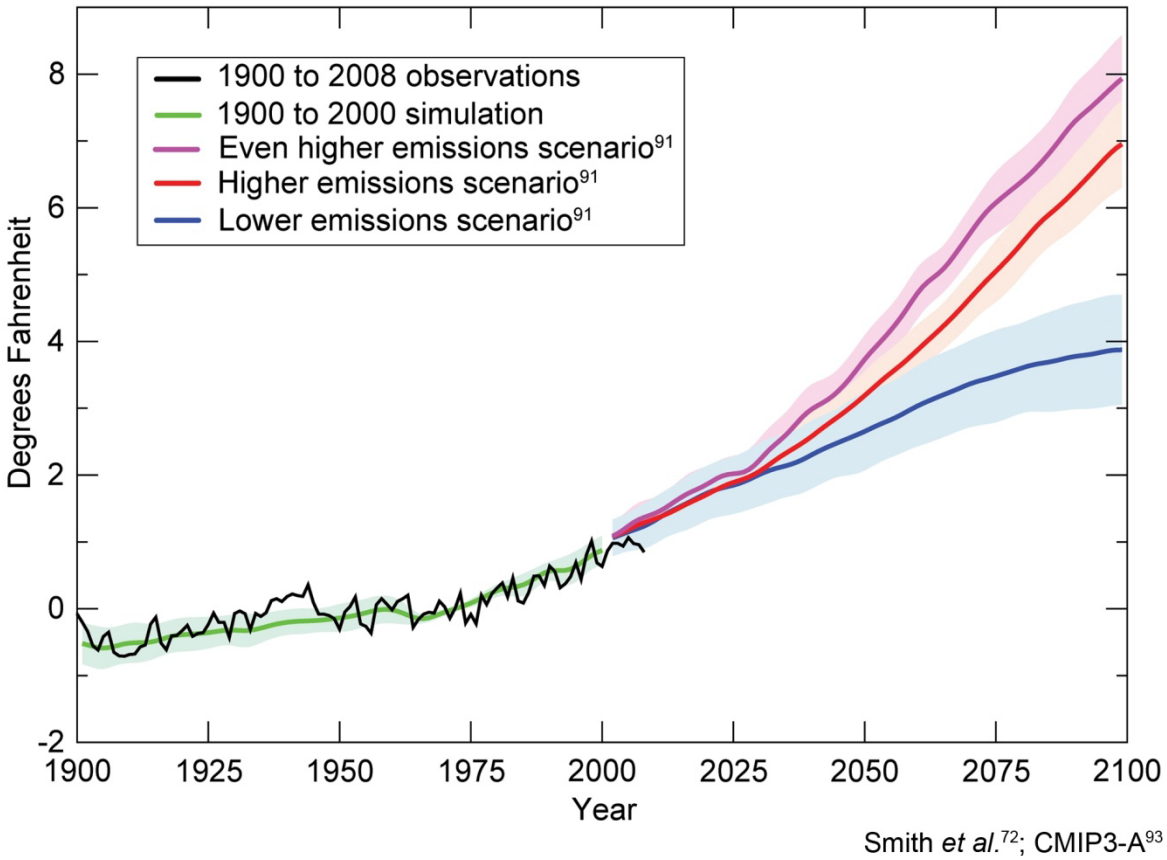

FIGURE B2

Observed and projected changes in the global average temperature under three IPCC emissions scenarios. The shaded areas show the likely ranges and the lines show the central projections from a set of climate models. Changes are relative to the 1960-1979 average.

SOURCE: *Global Climate Change Impacts in the United States* (2009), National Oceanic and Atmospheric Administration (NOAA).

Assessments

- **Foldable®**
  Students will design a comprehensive Foldable® demonstrating their understanding of Module II, *Factors Influencing Temperature*. This is a creative and research tested method for students of all ages to express their understanding of content and concepts. Go to the assessment folder to a rubric for assessing Foldables and other graphic organizers.
- **Concept Quiz –** found on page 9
- **Essay –** found on page 13

LESSON 9-APPENDIX

WEB ADDRESSES FOR HYPER LINKS
VOCABULARY

- **Climate forcing**
  http://climatechange.ucdavis.edu/terms.html
- **Climate feedback**
  http://en.wikipedia.org/wiki/Climate_feedback#Feedback
- **Climate models**
  http://www.wordiq.com/definition/Climate_model
- **Radiative forcing**
  http://en.wikipedia.org/wiki/Climate_forcing

LESSON 9-STANDARDS

National Science Education Standards

Unifying Concepts and Processes

- Systems, Order, and Organization
- Evidence, Models, and Explanations
- Change, Constancy, and Measurement
- Equilibrium

Standard A – Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Standard B – Physical Science

- Conservation of energy
- Interactions of energy and matter

Standard D – Earth and Space Science

- Energy in the earth system
- Geochemical cycles

Standard E – Science and Technology

- Abilities of technological design
- Understandings about science and technology

Standard F – Science in Personal and Social Perspectives

- Natural resources
- Environmental quality
- Natural and human induced hazards
- Science and technology in local, national, and global challenges

Standard G – History and Nature of Science

- Science as a human endeavor
- Nature of scientific knowledge
- Historical perspectives

National Education Technology Standards

Standard 1: Creativity and Innovation

- Use models and simulations to explore complex systems and issues
- Identify trends and forecast possibilities

National Council of Teachers of Mathematics Education Standards

Measurement

- Understand measurable attributes

Data Analysis and Probability

- Develop and evaluate inferences and predictions that are based on data

Process

- Connections
  - Recognize and apply mathematics in contexts outside of mathematics
- Representation
  - Use representations to model and interpret physical, social, and mathematical phenomena

Climate Literacy Principles

Principle 1: The sun is the primary source of energy for Earth's climate system.

Principle 2: Climate is regulated by interactions among components of the Earth system.

Principle 4: Climate varies over space and time through both natural and man-made processes.

Principle 5: Our understanding of the climate system is improved through observations, theoretical studies, and modeling.

Principle 6: Human activities are impacting the climate system.

Energy Literacy Principles

Principle 1: Energy is a measurable quantity that follows physical laws.
Principle 2: Physical Earth processes are the result of energy flow through the earth system.
Principle 5: Individuals and communities make energy decisions every day.
Principle 6: The amount of energy human society uses depends on many factors and can be reduced in many ways.
Principle 7: The energy choices made by individuals and societies affect quality of life.

LESSON 9-ESSENTIAL QUESTIONS ANSWER KEY

Making Connections-1

1. How much radiative forcing has been caused by CO_2 emitted to the atmosphere since 1750? How confident are scientists in this assessment?
   [About 1.7 W/m^2, the largest of any single forcing agent. The range of uncertainty is small indicating that scientists are highly confident in this number.]

2. What other gases in the atmosphere have a greenhouse effect?
   [Methane (CH_4), Nitrous Oxide (N_2O), and Halocarbons (CFC's and other human-made compounds) are all long-lived gases that have a warming influence. Ozone (O_3) has a warming influence in the troposphere and a cooling influence in the stratosphere. Water vapor in the stratosphere has a small warming effect.]

3. What forcings have a cooling influence on the climate?
   [Changes in land use that affect the surface reflectivity have had a net cooling effect. These include clearing of forests (which are typically quite dark in color) to make way for agricultural uses (which tend to be much brighter surfaces). Small air-borne particles can reflect sunlight directly and can make clouds brighter. Finally, stratospheric ozone has a small cooling effect, although its magnitude is uncertain and may even be positive.]

4. What is the total net influence of human activities on the climate? Is there any chance that human activities could have caused cooling or even no net effect on climate? How does it compare in magnitude to the total of all natural influences?
   [The net influence of human activities is a positive radiative forcing of about 1.6 W/m^2. The error bars only go as low as 0.6 W/m^2, indicating that there is little chance that humans have not had a net warming influence on the climate. The natural influences are much smaller magnitude, only about 0.2 W/m^2, and also would cause warming.]

Making Connections-2

a. Estimate how much temperatures have increased since 1900 and since the 1960-1979. When has most of the warming happened since 1900?
   [Temperatures have increased about 1.4F since 1900 and about 1F since 1960-1979. Most of the warming has happened in the last 30-40 years.]

2. Why do think there are so many wiggles in the temperature record?
   [Temperature will respond to year-to-year natural variability, for example, from normal variations in how much energy the Earth gets from the Sun or from what phase of El Nino we are in.]

Making Connections-3

1. How much is temperature projected to rise under each scenario from 2000-2099?
   [Lower emissions scenario = 3°F; Higher emissions scenario = 6°F; Even higher emissions scenario = 7°F]

2. Compare the projected temperature changes for the 21st century to what was observed during the 20th century.
   [These temperature increases are all much greater than the increase over the 20th century. Lower emissions scenario = about twice as much warming; Higher emission scenario = about 4 times as much warming; Even higher emissions scenario = about 5 times as much warming.]

3. What might you hypothesize about the magnitude of impacts (e.g., sea level rise, changes to ecosystems; changes in extreme weather) that these different climate scenarios might bring?
   [We have already seen some significant impacts from the small amount of warming experienced over the 20th century. If the next century has many times more warming, then we would expect the impacts to become more severe.]

Making Connections-4

1. Estimate what the CO_2 levels were in 1980, based on the Keeling Curve.
   [336 ppm]

2. Estimate how much CO_2 has increased from 1980 to 2010.
   [388 ppm – 336 ppm = 52 ppm]

3. CO_2 was approximately 290 ppm in 1750 when humans began burning lots of fossil fuels. Estimate how much CO2 has increased from 1750 to 2010.
   [388 ppm – 290 ppm = 102 ppm]

4. Calculate the fraction of CO_2 that has been emitted from 1980 to 2010. This fraction roughly corresponds to the amount of radiative forcing due to CO_2 emitted during this timeframe.
   [52 ppm / 102 ppm = 0.51]

5. Do you think that stopping CO_2 emissions in 1980 could have had a significant effect on the trend in temperature over the last 30 years? Why or why not? What are some practical reasons why it is difficult to completely halt emissions?
   [It is likely that changing our pollution practices 30 years ago would have an effect. Nearly half of the CO_2 added to the atmosphere has been emitted and most of the warming has taken place during this time. However, it is not practical to just turn off CO_2 emissions. People across the world depend on fossil fuels for electricity production and transportation fuels. Major investments would be needed to develop and deploy alternatives.]

Name: _____ Date: _____

Science Concept Quiz
Lesson 9: Conceptualizing Module II

Use Figure 1 to make your best answer choice. **Which statement is correct according to Figure 1?**

A. Stratospheric water vapor is a cooling influence.
B. Scientists estimate a large range of uncertainty for the greenhouse gases.
C. Ozone is a warming influence.
D. Human activities greatly surpass the total natural cooling and warming influences.

_____ points out of 20

I. Answer

A.◯ B.◯ C.◯ D.◯

_____ points out of 15

II. Main Science Concept

1. Reading a graph
2. Making predictions
3. Warming and cooling influences
4. Greenhouse gases

_____ points out of 25

III. Provide the reasoning for choosing your answer in part II.

_____points out of 40

IV. Why are the other responses in part I not the best answer choice?

1.

2.

3.

4.

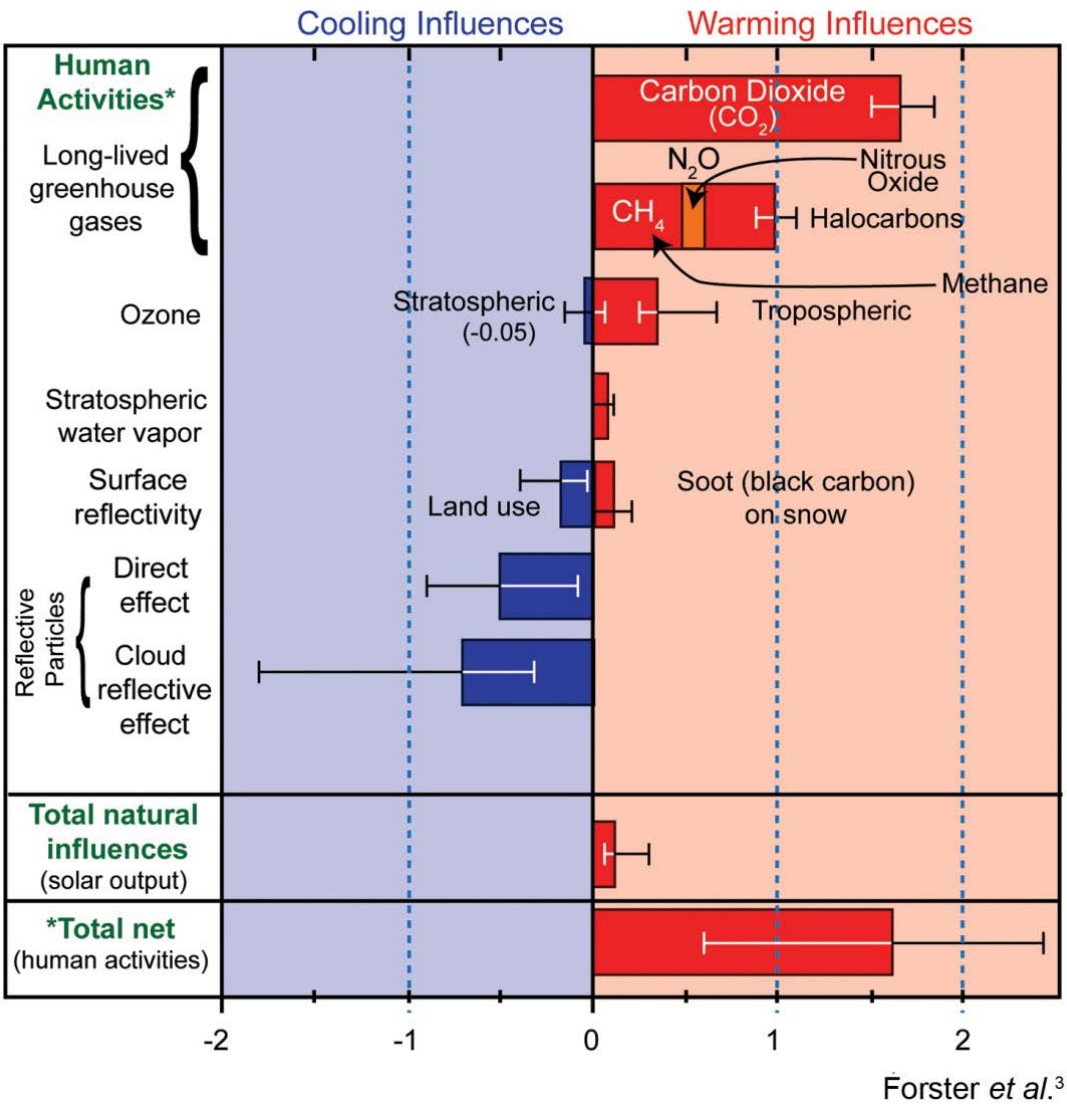

Figure 1

The amount of warming influence (red bars) and cooling influences (blue bars) that different factors have had on Earth's climate over the industrial age (From about 1750 to the present). Results are in W/m^2. The thin lines on each bar provide an estimate of the range of uncertainty.

SOURCE: *Global Climate Change Impacts in the United States* (2009), National Oceanic and Atmospheric Administration (NOAA).

Teacher Answer Key

1. D

2. 1

3. Answers will vary. Regardless of if you know what the graph is taking about, by observing the graph carefully one can answer the question successfully.

4. Answers will vary.

   A) Stratospheric water vapor is a warming influence based on the graph.

   B) According to the graph there is a small scale of uncertainty about the greenhouse gases influence on the earth system.

   C) Ozone is both a warming and cooling influence.

   D) This is the correct answer. You can compare the natural and human activities to see that human activities far out way the natural occurrences and patterns.

Student Name
Teacher/Class
Date

Lesson 9 Essay Assessment
Conceptualizing Module II

Explain what you understand about factors that influence temperature based on knowledge learned in Module II. Be sure to refer to the expectations at the right.

What Is the Expectation?

Use student readings, peer discussions, and science notebook data to support your position

Visual representations if applicable

Key vocabulary

Evidence of on grade level spelling and grammar usage