NESTA Session

MEL2—Thinking Scientifically in a Changing World

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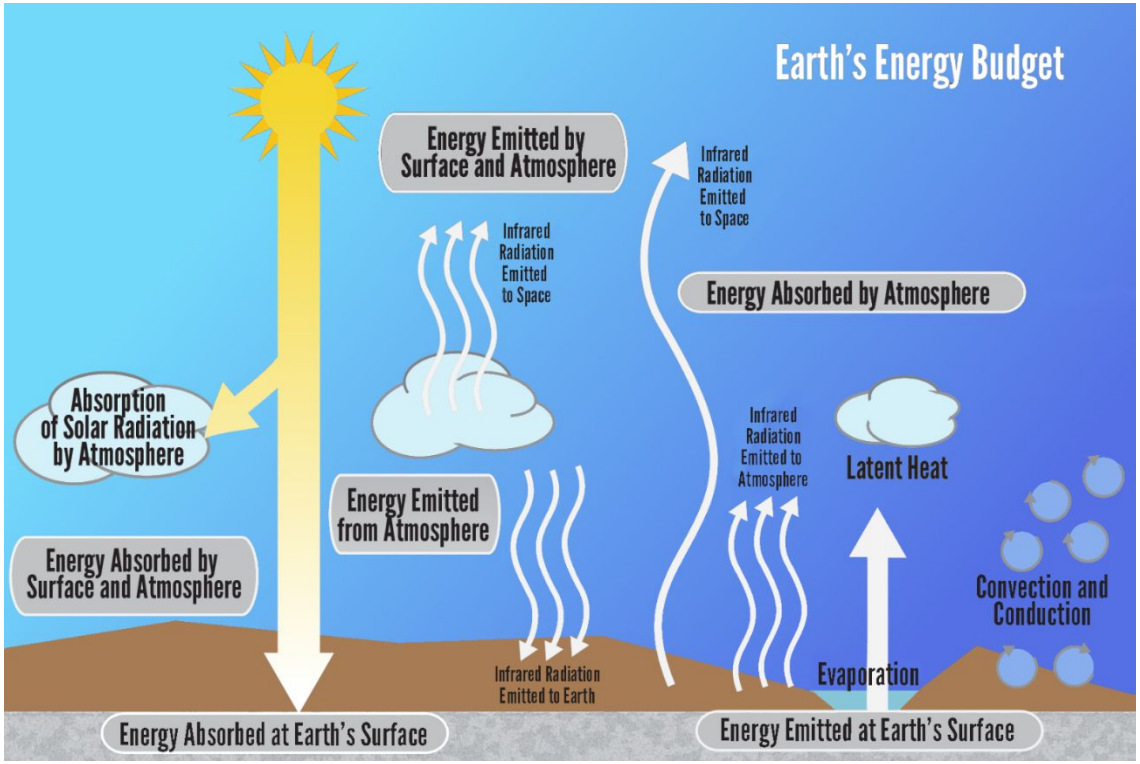

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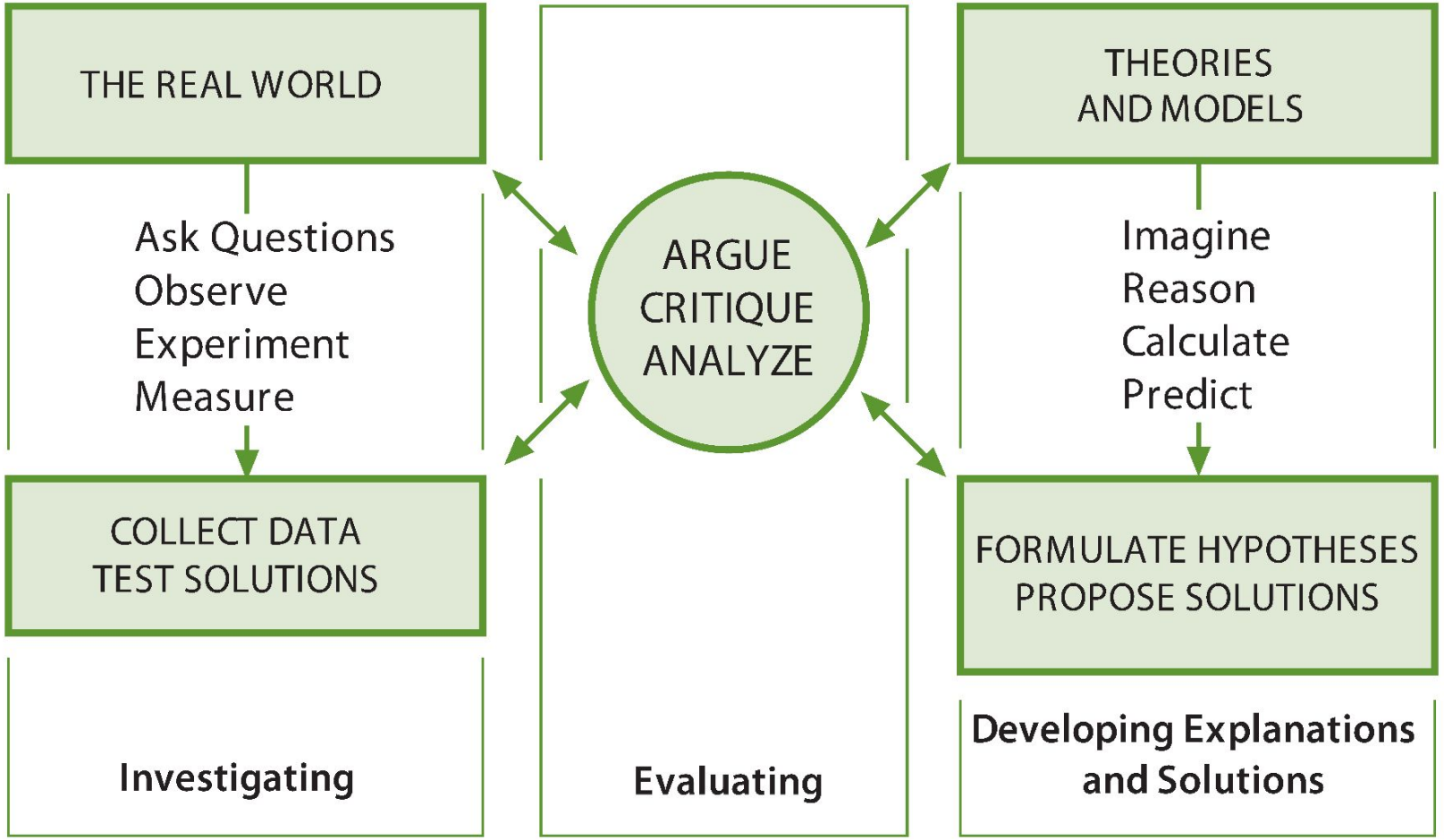
Due to complexity, abstractness, or controversy, teaching about some topics can be a challenge

Teaching the science alone isn't enough…. We have to aim for scientific literacy

Scientific literacy = knowing both: (1) *what* scientists know & (2) *how* scientists know



Evaluation as argument, critique, and analysis is central to scientific thinking and knowledge construction (NRC, 2012)

The activities we'll talk about today connect to NGSS/3D learning's SEPs and CCCs

Science & Engineering Practices:

- Engaging in Argument from Evidence
- Constructing Explanations from Evidence
- Developing & ***Using Models***

Crosscutting Concepts:

- Cause & Effect
- Systems & System Models
- Energy & Matter
- Varies by scaffold

You may already be familiar with the Claim-Evidence-Reasoning (CER) approach

- Claims: A proposed answer to a question
- Evidence: The information used in an argument to support the claim
- Reasoning: Justification that links the claim and evidence.

Scientists construct MODELS to explain evidence

Evidence is the foundation for both claims and models

CLAIMS

- An answer to a question
- An assertion based on results of an investigation
- Requires justification to support the claim

MODELS

- An explanation of a phenomenon
- A hypothesis that leads to new questions
- Predicts or describes how and why a phenomenon occurs

Models alone are not sufficient to support scientific thinking

<u>Models must be coordinated with lines of evidence</u> to help build an argument about a particular phenomenon and its systematic relationships. (NRC, 2012)

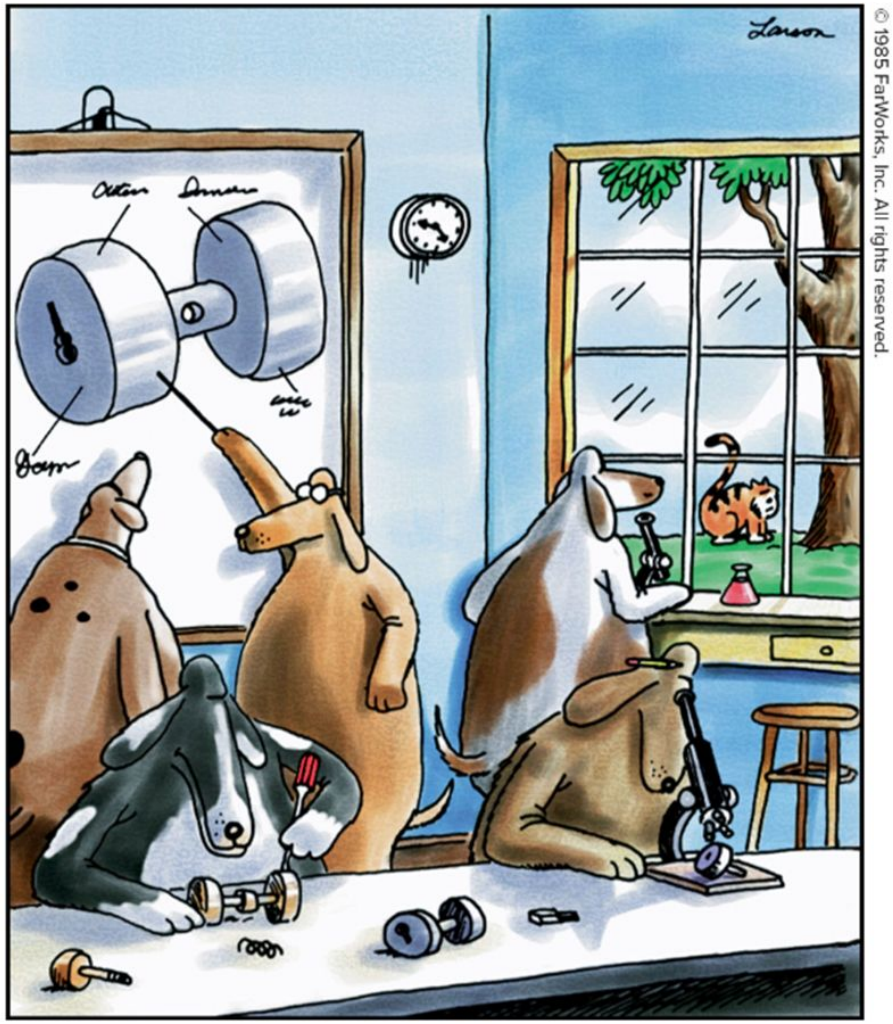
How are scientific models evaluated?

Scientific Evaluations and Judgments about Knowledge

Scientists make judgments about both evidence and explanations about phenomena

For example, scientists judge the credibility and reliability of evidence

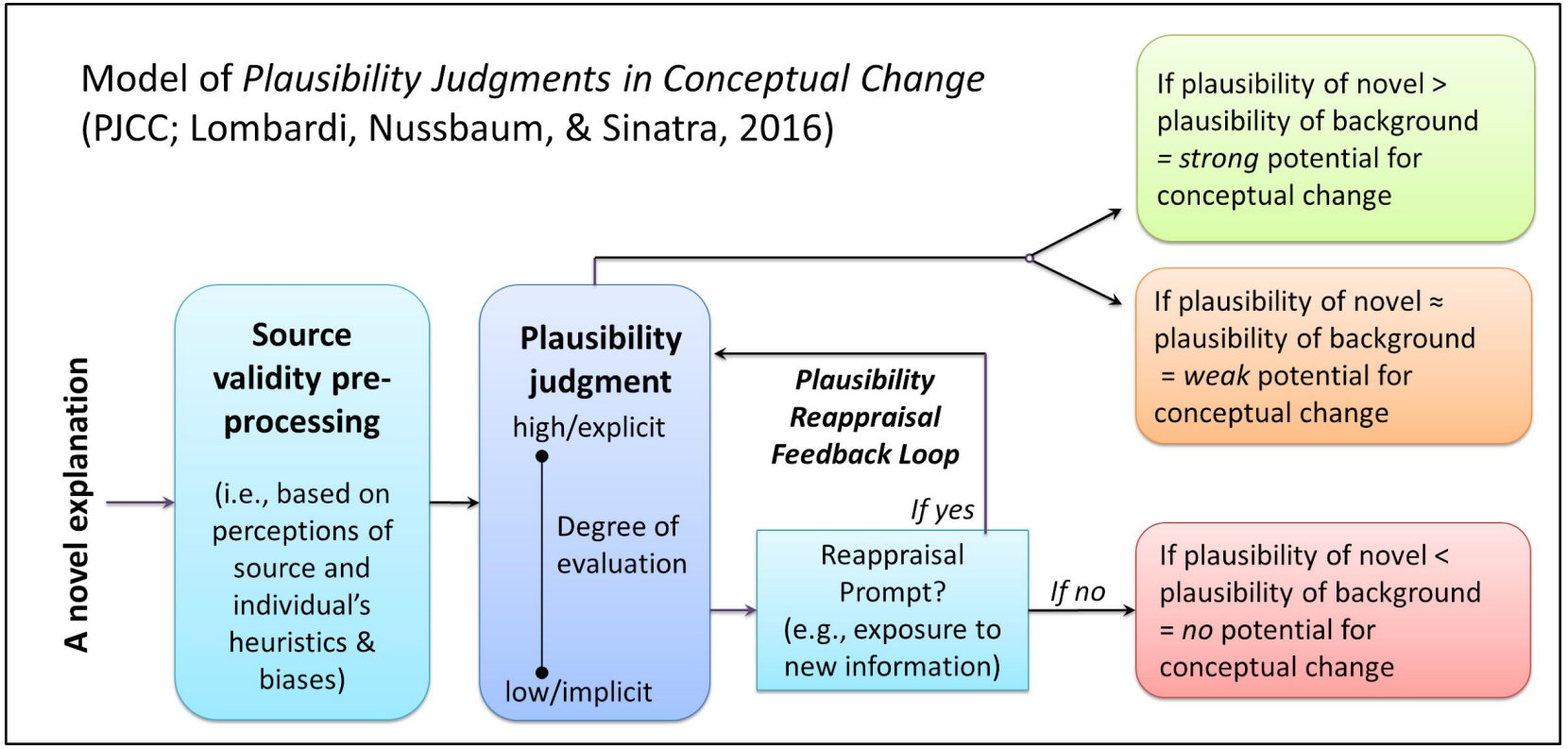
Scientists also evaluate the plausibility of explanations in light of other alternatives



Knowing how it could change the lives of canines everywhere, the dog scientists struggled diligently to understand the Doorknob Principle.

Our plausibility judgments are tentative and changeable

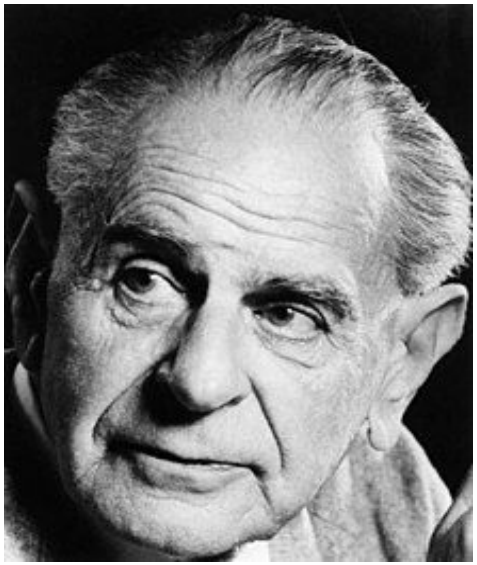
Shifts in plausibility judgments toward the scientific can help us learn more deeply



Plausibility and Falsifiability

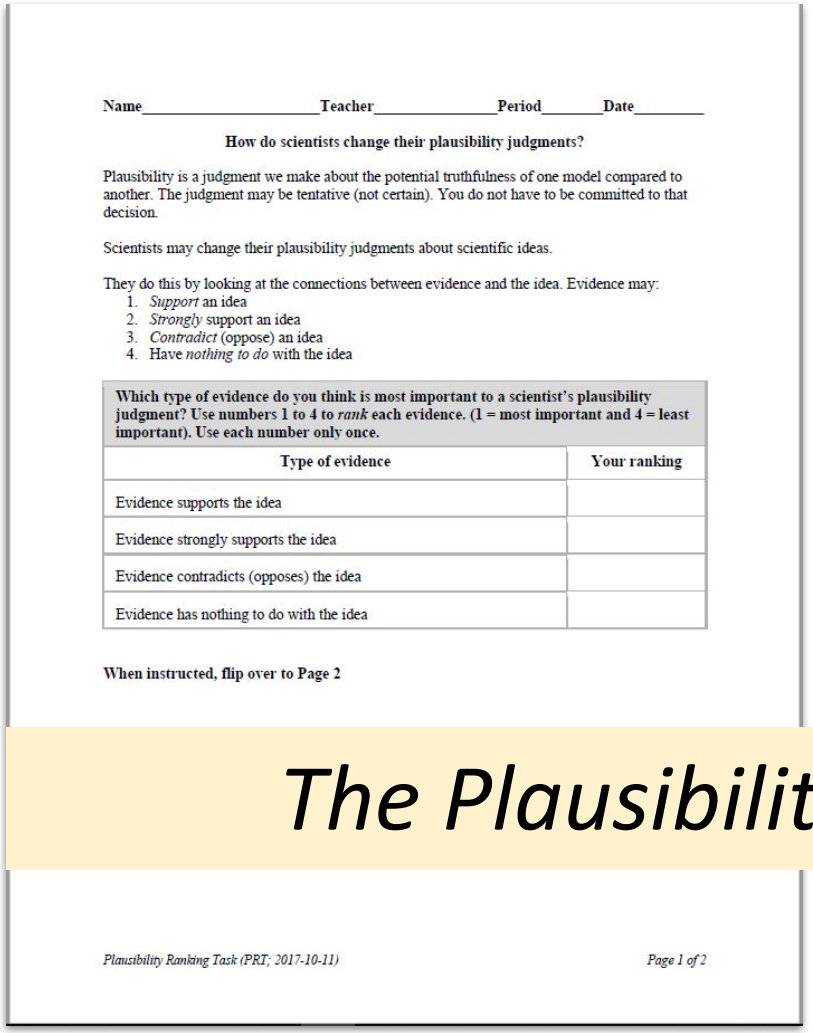
Falsifiability makes explanations scientific, that is, scientific explanations must be open be able to be proven wrong (i.e., false).

--Karl Popper



The only consistent characteristic across disciplines is that scientific explanations are open to revision in light of new evidence (NGSS, 2013, Vol 2, p. 96)

Introducing Students to Plausibility



Name_____Teacher_____Period_____Date_____

How do scientists change their plausibility judgments?

Plausibility is a judgment we make about the potential truthfulness of one model compared to another. The judgment may be tentative (not certain). You do not have to be committed to that decision.

Scientists may change their plausibility judgments about scientific ideas.

They do this by looking at the connections between evidence and the idea. Evidence may:

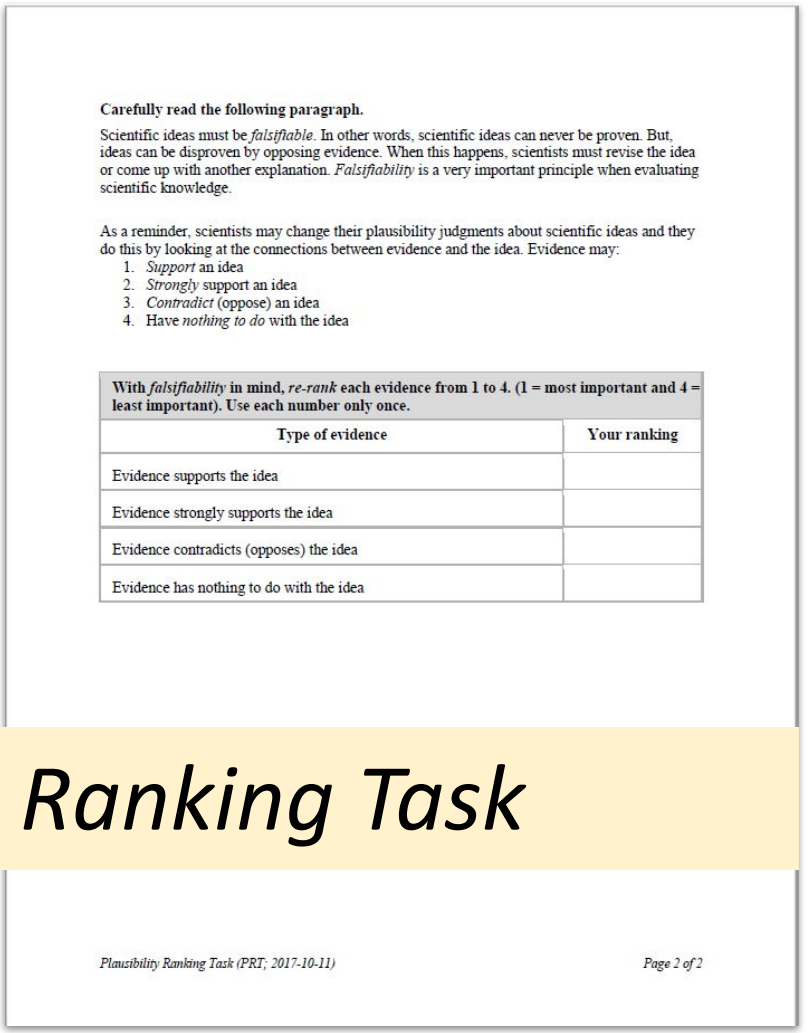
1. *Support* an idea
2. *Strongly* support an idea
3. *Contradict* (oppose) an idea
4. Have *nothing to do* with the idea

Which type of evidence do you think is most important to a scientist's plausibility judgment? Use numbers 1 to 4 to *rank* each evidence. (1 = most important and 4 = least important). Use each number only once.

Type of evidence	Your ranking
Evidence supports the idea	
Evidence strongly supports the idea	
Evidence contradicts (opposes) the idea	
Evidence has nothing to do with the idea	

When instructed, flip over to Page 2

Plausibility Ranking Task (PRT; 2017-10-11) *Page 1 of 2*



Carefully read the following paragraph.

Scientific ideas must be *falsifiable*. In other words, scientific ideas can never be proven. But, ideas can be disproven by opposing evidence. When this happens, scientists must revise the idea or come up with another explanation. *Falsifiability* is a very important principle when evaluating scientific knowledge.

As a reminder, scientists may change their plausibility judgments about scientific ideas and they do this by looking at the connections between evidence and the idea. Evidence may:

1. *Support* an idea
2. *Strongly* support an idea
3. *Contradict* (oppose) an idea
4. Have *nothing to do* with the idea

With *falsifiability* in mind, *re-rank* each evidence from 1 to 4. (1 = most important and 4 = least important). Use each number only once.

Type of evidence	Your ranking
Evidence supports the idea	
Evidence strongly supports the idea	
Evidence contradicts (opposes) the idea	
Evidence has nothing to do with the idea	

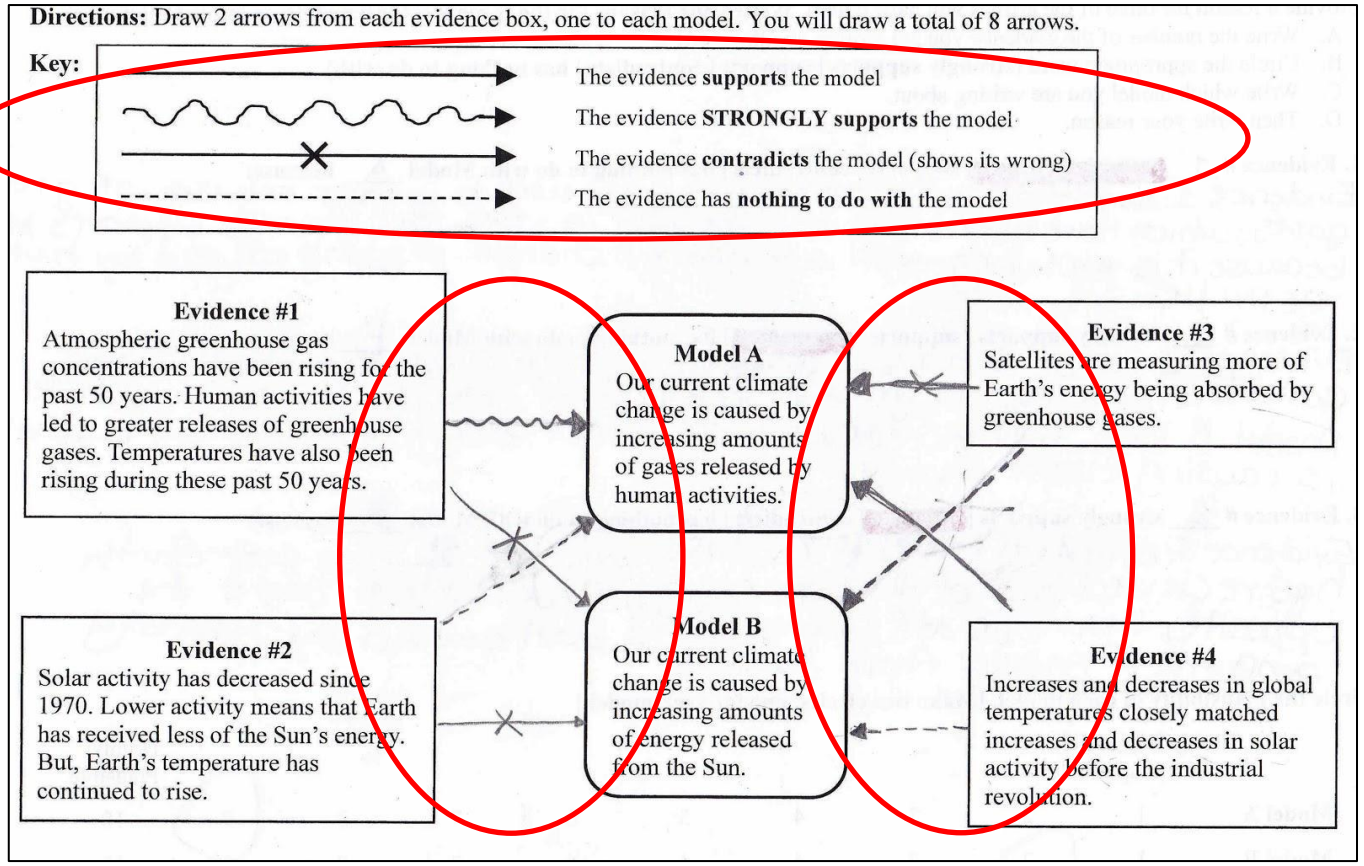
Plausibility Ranking Task (PRT; 2017-10-11) *Page 2 of 2*

The Plausibility Ranking Task

The Model-Evidence Link Diagram

Classroom instructional scaffolds can help make students' evaluations explicit, thoughtful, & scientific

Chinn & colleagues (2012, 2014)

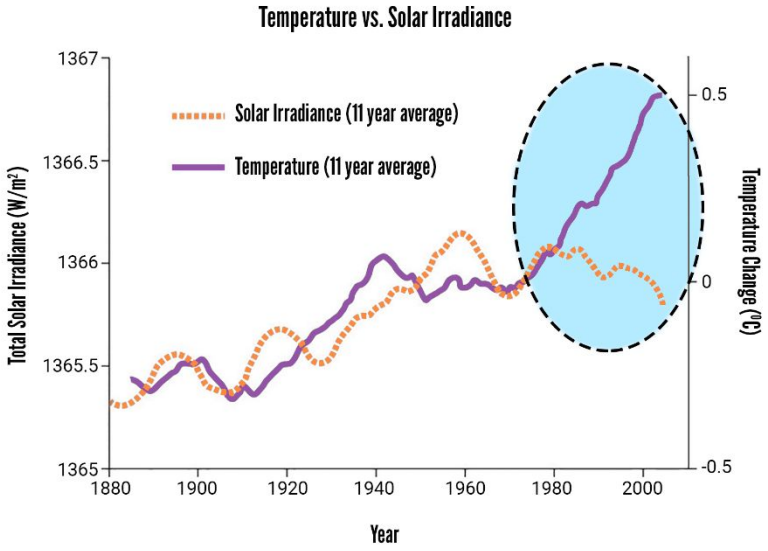


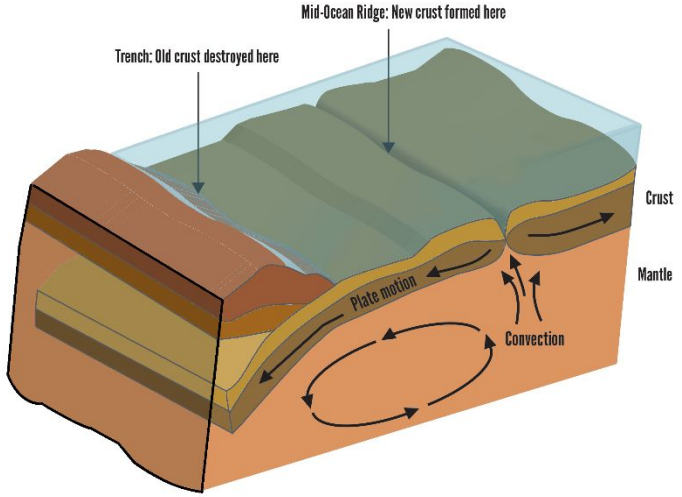
Example of student completed Model-Evidence Link (MEL) diagram

Scientific evaluations may also promote students' reappraisal of their initial plausibility judgments & knowledge reconstruction (Lombardi et al., 2016a)

The first four MELs we developed cover the areas of geology, hydrology, climate, and astronomy

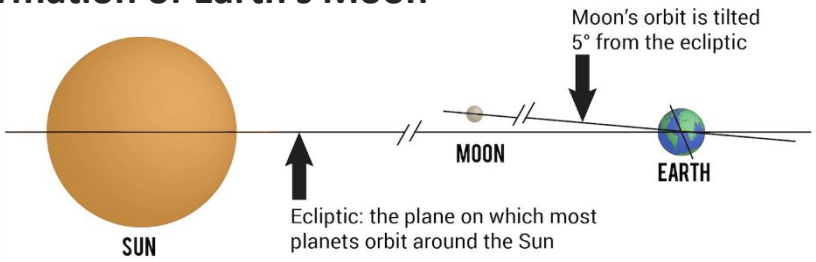
Causes of current climate change

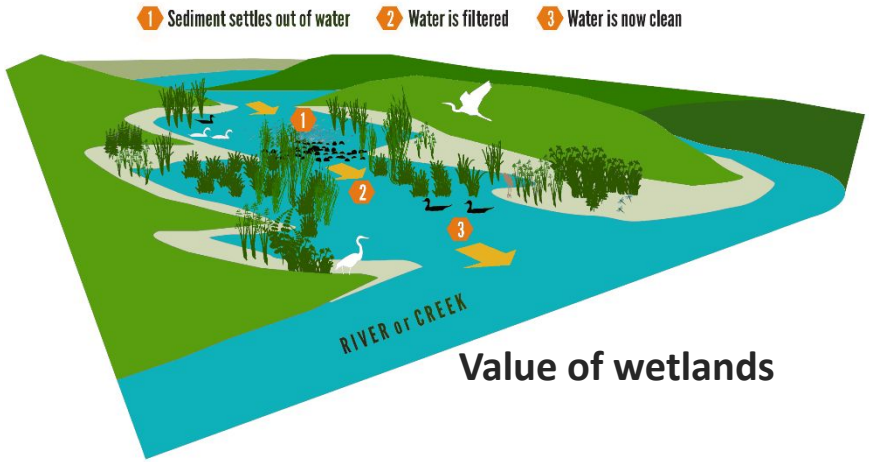




Hydraulic fracturing & earthquakes

Formation of Earth's Moon





Value of wetlands

MEL Step 1: Model Plausibility Ratings

When teaching the MEL, introduce the explanatory models and have students rate model plausibility

Plausibility of Models Explaining Climate Change

Name: _____ **Date:** _____ **Teacher:** _____ **Period:** ____

Please work on this individually.

Read the following information carefully.

Humans create *models* to help explain things.

Below are two models. These provide different explanations for why global temperatures have increased over the past 100 years and average sea levels have increased over the past 50 years.

Model A: Climate change is caused by humans who are releasing gases into the atmosphere.

A person who supports this model makes the following argument:

A few gases in Earth's atmosphere prevent some of Earth's energy from escaping out into space. Human activities are increasing the amount of these gases in the atmosphere. Therefore, humans are causing climate change.

Model B: Climate change is caused by increasing amounts of energy released from the Sun.

A person who supports this model makes the following argument:

The Sun is the main source of energy for planet Earth. Scientists have shown that for thousands of years Earth's average temperature increases when the Sun releases more energy. Therefore, the Sun is causing climate change.

Plausibility is a judgment we make about the potential truthfulness of one model compared to another. The judgment may be tentative (not certain). You do not have to be committed to that decision.

Circle the plausibility of each model. [Make two circles, one for each model.]

	Greatly implausible (or even impossible)									Highly plausible
Model A	1	2	3	4	5	6	7	8	9	10
Model B	1	2	3	4	5	6	7	8	9	10

MEL Step 2: Examining the Evidence

Complete the MEL diagram using the evidence texts as a resource

Name: _____ **Date:** _____ **Teacher:** _____ **Period:** _____

If you worked with other students, their name(s): _____

Directions: Draw 2 arrows from each evidence box, one to each model. You will draw a total of 8 arrows.

Key:

- The evidence **supports** the model
- The evidence **STRONGLY supports** the model
- The evidence **contradicts** the model (shows its wrong)
- The evidence has **nothing to do with** the model

Evidence #1
Atmospheric greenhouse gas concentrations have been rising for the past 50 years. Human activities have led to greater releases of greenhouse gases. Temperatures have also been rising during these past 50 years.

Model A
Our current climate change is caused by increasing amounts of gases released by human activities.

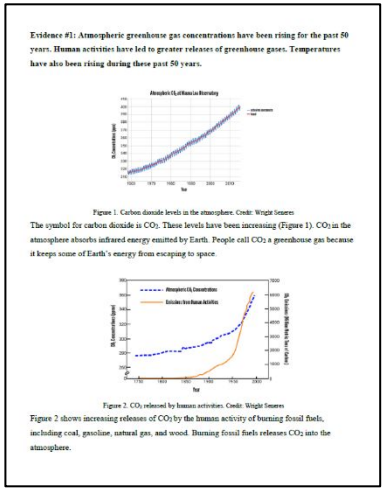
Evidence #3
Satellites are measuring more of Earth's energy being absorbed by greenhouse gases.

Evidence #2
Solar activity has decreased since 1970. Lower activity means that Earth has received less of the Sun's energy. But, Earth's temperature has continued to rise.

Model B
Our current climate change is caused by increasing amounts of energy released from the Sun.

Evidence #4
Increases and decreases in global temperatures closely matched increases and decreases in solar activity before the industrial revolution.

Students would work in groups and come to consensus about the arrows drawn



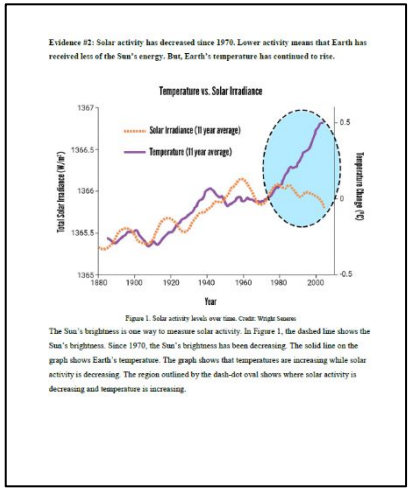
Evidence #1: Atmospheric greenhouse gas concentrations have been rising for the past 50 years. Human activities have led to greater releases of greenhouse gases. Temperatures have also been rising during these past 50 years.

Figure 1. Carbon dioxide levels in the atmosphere. Credit: Wright Sources

The symbol for carbon dioxide is CO_2. These levels have been increasing (Figure 1). CO_2 in the atmosphere absorbs infrared energy emitted by Earth. People call CO_2 a greenhouse gas because it keeps some of Earth's energy from escaping to space.

Figure 2. CO_2 released by human activities. Credit: Wright Sources

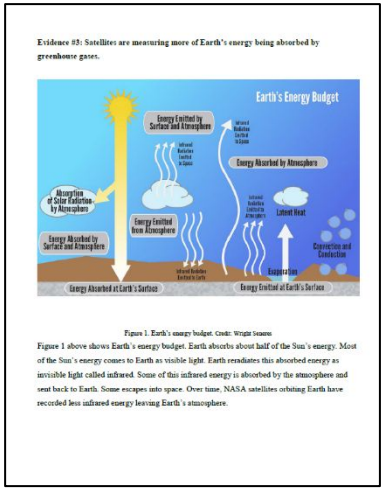
Figure 2 shows increasing releases of CO_2 by the human activity of burning fossil fuels, including coal, gasoline, natural gas, and wood. Burning fossil fuels releases CO_2 into the atmosphere.



Evidence #2: Solar activity has decreased since 1970. Lower activity means that Earth has received less of the Sun's energy. But, Earth's temperature has continued to rise.

Figure 1. Solar activity levels over time. Credit: Wright Sources

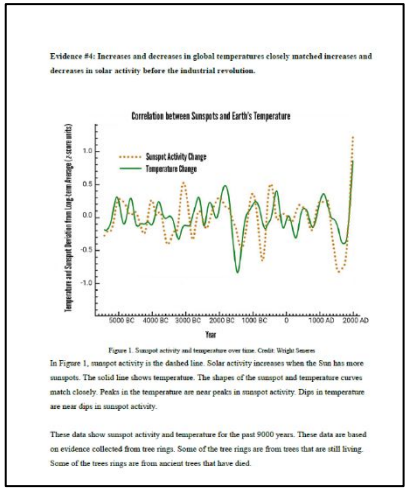
The Sun's brightness is one way to measure solar activity. In Figure 1, the dashed line shows the Sun's brightness. Since 1970, the Sun's brightness has been decreasing. The solid line on the graph shows Earth's temperature. The graph shows that temperatures are increasing while solar activity is decreasing. The region outlined by the dash-dot oval shows where solar activity is decreasing and temperature is increasing.



Evidence #3: Satellites are measuring more of Earth's energy being absorbed by greenhouse gases.

Figure 1. Earth's energy budget. Credit: Wright Sources

Figure 1 above shows Earth's energy budget. Earth absorbs about half of the Sun's energy. Most of the Sun's energy comes to Earth as visible light. Earth reradiates this absorbed energy as invisible light called infrared. Some of this infrared energy is absorbed by the atmosphere and sent back to Earth. Some escapes into space. Over time, NASA satellites orbiting Earth have recorded less infrared energy leaving Earth's atmosphere.



Evidence #4: Increases and decreases in global temperatures closely matched increases and decreases in solar activity before the industrial revolution.

Figure 1. Sunspot activity and temperature over time. Credit: Wright Sources

In Figure 1, sunspot activity is the dashed line. Solar activity increases when the Sun has more sunspots. The solid line shows temperature. The shapes of the sunspot and temperature curves match closely. Peaks in the temperature are near peaks in sunspot activity. Dips in temperature are near dips in sunspot activity.

These data show sunspot activity and temperature for the past 9000 years. These data are based on evidence collected from tree rings. Some of the tree rings are from trees that are still living. Some of the trees rings are from ancient trees that have died.

MEL Step 3: Explanation Task

1. Please work on this part individually after you complete your diagram. Now that you have completed the diagram, reconsider the plausibility of Models A and B. Circle the plausibility of each model. [Make two circles, one for each model.]

	Greatly implausible (or even impossible)									Highly plausible
Model A	1	2	3	4	5	6	7	8	(9)	10
Model B	1	2	3	4	5	6	(7)	8	9	10

What were your previous rankings? Model A: 9 **Model B:** 7

2. Did the plausibility of Model A and/or Model B change after you completed the diagram? (Yes) or No [Circle One]

3. Which arrows changed your plausibility judgments about the models? If your plausibility judgment did not change, which arrows supported your original plausibility judgments? Use the following steps to provide two explanations for why your plausibility judgments did or did not change.

1) Write the number of the evidence you are writing about. [Note: it is okay to include more than one evidence.]
2) Circle the appropriate word (**strongly supports | supports | contradicts | has nothing to do with**).
3) Write which model you are writing about. [Note: it is okay to include both models.]
4) Then write your reason.

Evidence # 1 **strongly supports | supports | contradicts | has nothing to do with Model** A **because:**

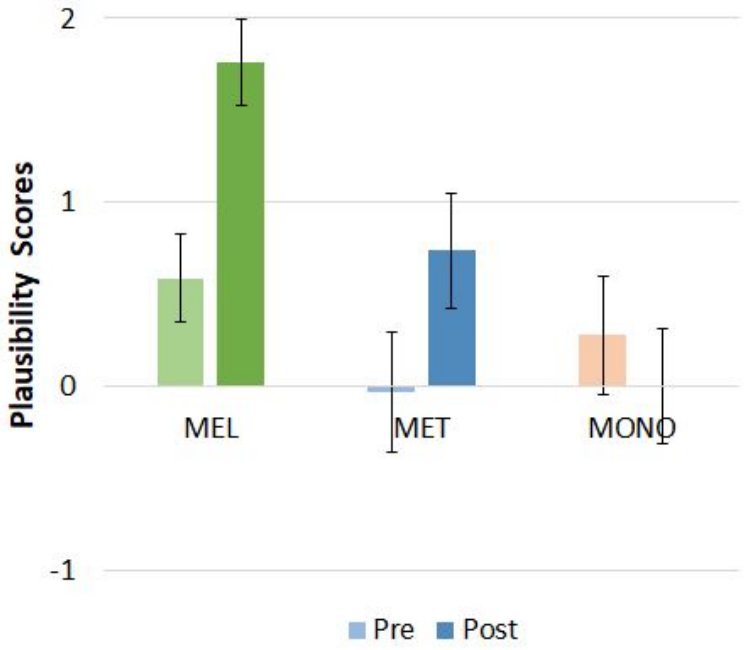
it shows how significant the wetlands are for the natural cycles, and that if they are taken away the cycles would suffer.

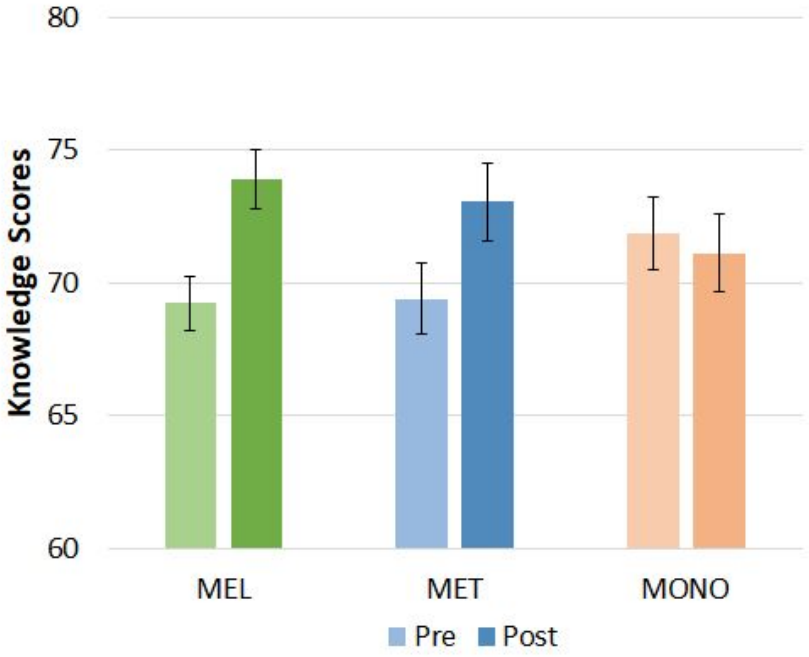
4. In your final ranking, did you rank either Model as "1" or "10?" Yes or (No) [Circle One] Why? Why not?

no because none of the evidence was intensely supportive nor not supportive at all.

Complete a written explanation task after completing the diagram and then re-rate plausibility of the models

Quasi-experimental results revealed that the pcMEL leads to plausibility shifts and increased knowledge



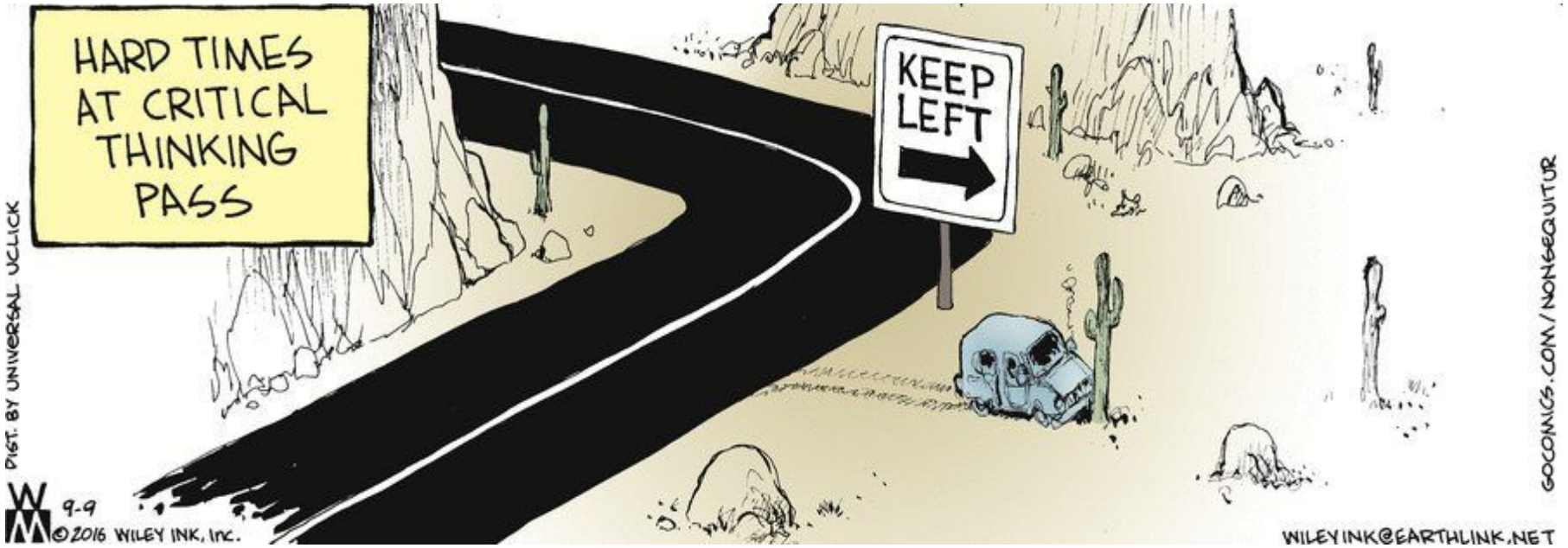


$F(2,61) = 5.67$, $p = .006$, medium effect size ($\eta^2 = .157$)

Wilks' $\lambda = .893$, $F(2,61) = 3.67$, $p = .03$, medium effect size ($\eta^2 = .107$)

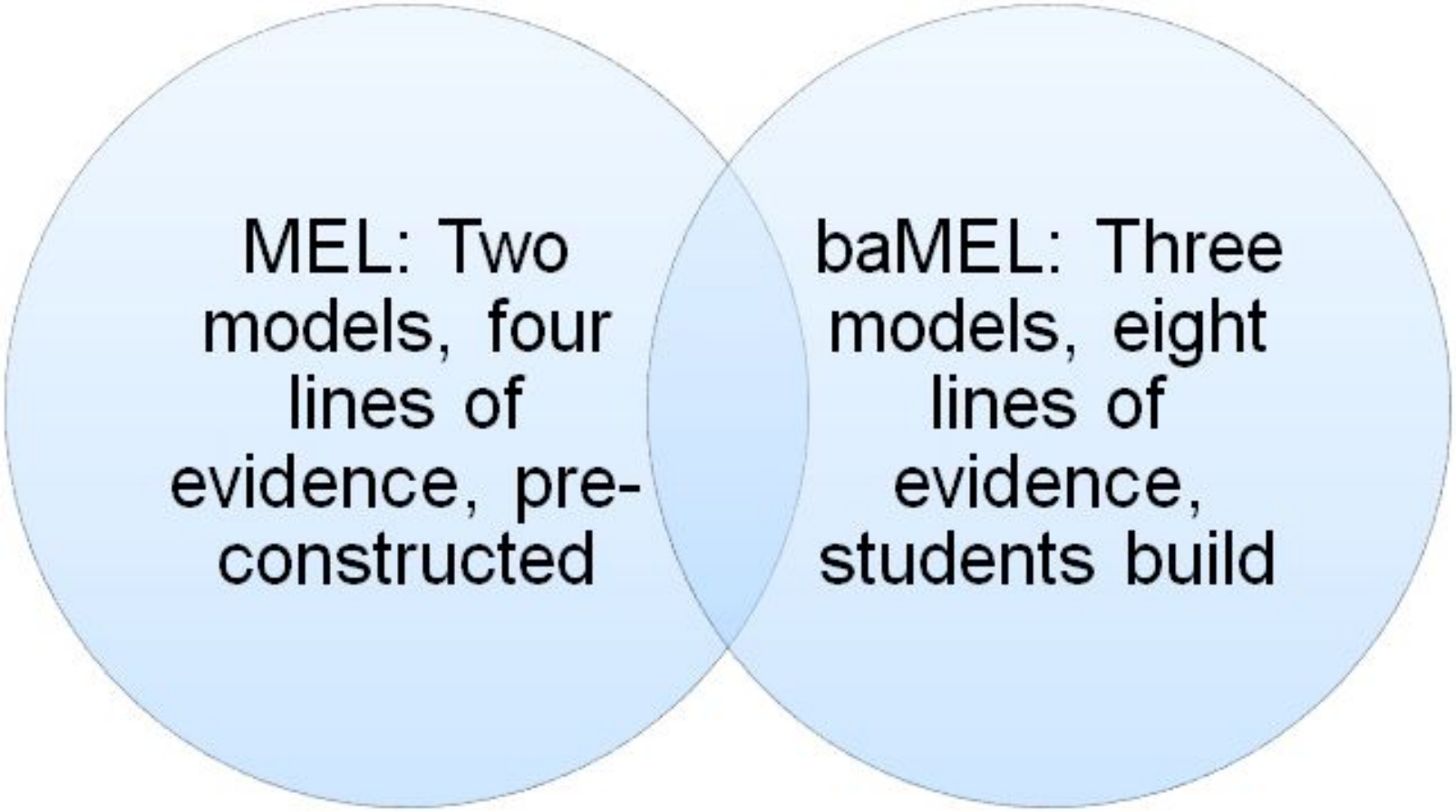
Lombardi, Bailey, Bickel, & Burrell (2018)

Our research shows that students make scientific evaluations and learn about these topics more deeply



But we are unsatisfied, because some students are not transferring their evaluative thinking outside of the classroom context

Introducing the build-a-MEL (baMEL)



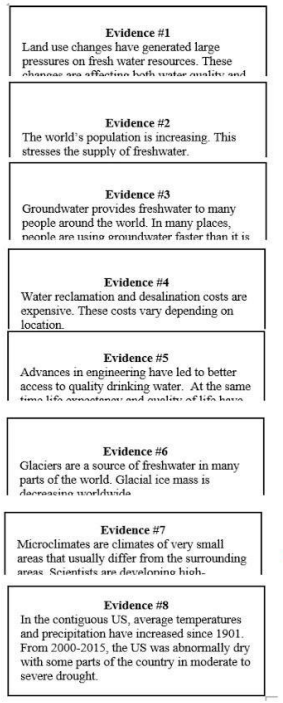
Students who exercise conceptual agency are authors of their own contributions, accountable to the classroom learning community, and have the authority to think about and solve problems (Nussbaum & Asterhan, 2016)

The sequence of baMEL activities takes about twice as long as the pre-constructed MEL (90-120 minutes)

1. Present 3 competing models & rate their plausibility

2. Read & discuss the 8 evidence texts & build the MEL

3. Complete the explanation task



Evidence #1
Land use changes have generated large pressures on fresh water resources. These changes are affecting both water quality and

Evidence #2
The world's population is increasing. This stresses the supply of freshwater.

Evidence #3
Groundwater provides freshwater to many people around the world. In many places, people are using groundwater faster than it is

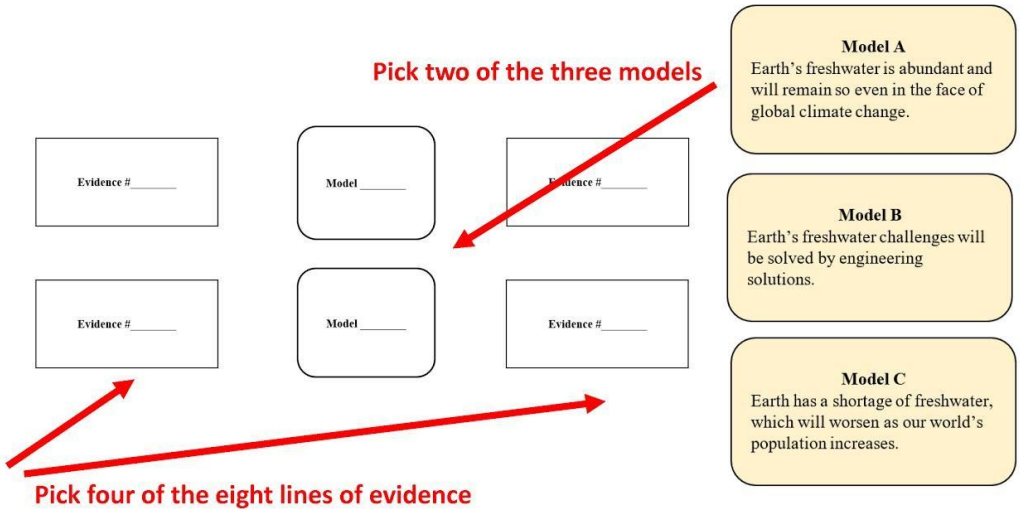
Evidence #4
Water reclamation and desalination costs are expensive. These costs vary depending on location.

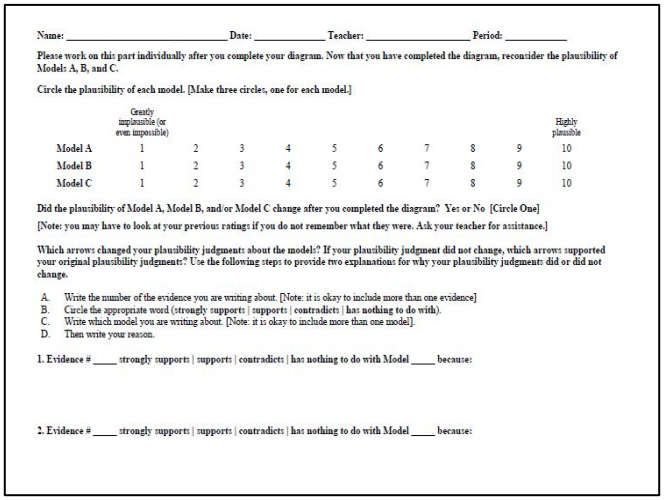
Evidence #5
Advances in engineering have led to better access to quality drinking water. At the same time life expectancy and quality of life have

Evidence #6
Glaciers are a source of freshwater in many parts of the world. Glacial ice mass is decreasing worldwide

Evidence #7
Microclimates are climates of very small areas that usually differ from the surrounding areas. Scientists are developing high-

Evidence #8
In the contiguous US, average temperatures and precipitation have increased since 1901. From 2000-2015, the US was abnormally dry with some parts of the country in moderate to severe drought.





Name: _____ Date: _____ Teacher: _____ Period: _____

Please work on this part individually after you complete your diagram. Now that you have completed the diagram, reconsider the plausibility of Models A, B, and C.

Circle the plausibility of each model. [Make three circles, one for each model.]

	Greatly implausible (or even impossible)									Highly plausible
Model A	1	2	3	4	5	6	7	8	9	10
Model B	1	2	3	4	5	6	7	8	9	10
Model C	1	2	3	4	5	6	7	8	9	10

Did the plausibility of Model A, Model B, and/or Model C change after you completed the diagram? Yes or No [Circle One]

[Note: you may have to look at your previous ratings if you do not remember what they were. Ask your teacher for assistance.]

Which arrows changed your plausibility judgments about the models? If your plausibility judgment did not change, which arrows supported your original plausibility judgments? Use the following steps to provide two explanations for why your plausibility judgments did or did not change.

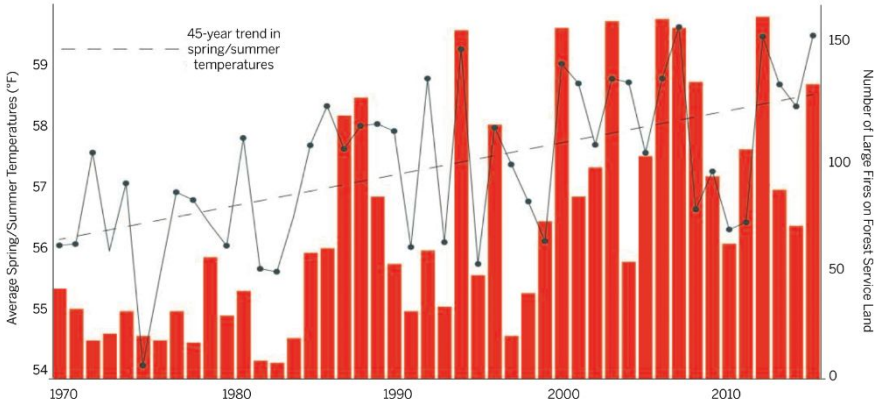
A. Write the number of the evidence you are writing about. [Note: it is okay to include more than one evidence]
B. Circle the appropriate word (strongly supports | supports | contradicts | has nothing to do with).
C. Write which model you are writing about. [Note: it is okay to include more than one model].
D. Then write your reason.

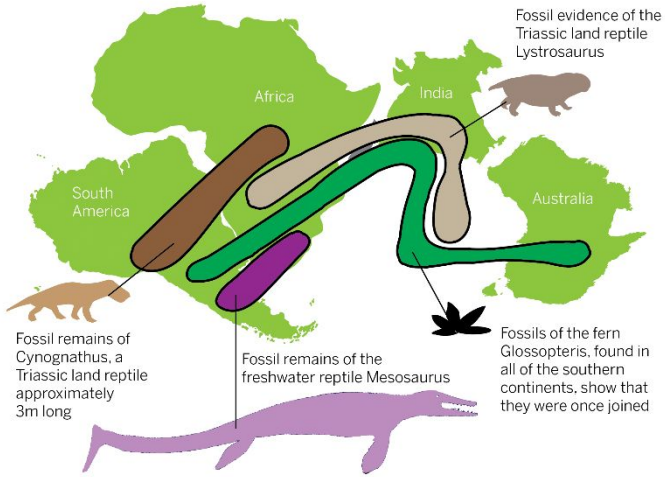
1. Evidence #____ strongly supports | supports | contradicts | has nothing to do with Model ____ because:

2. Evidence #____ strongly supports | supports | contradicts | has nothing to do with Model ____ because:

Similar to the pre-constructed MELs, the baMELs cover the areas of geology, hydrology, climate, & astronomy

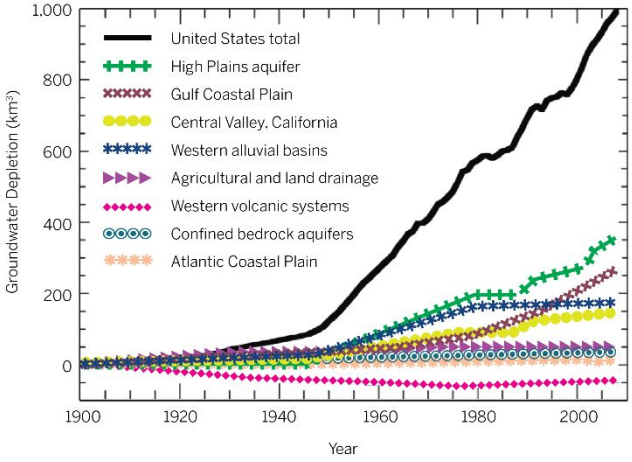
Extreme weather & climate change

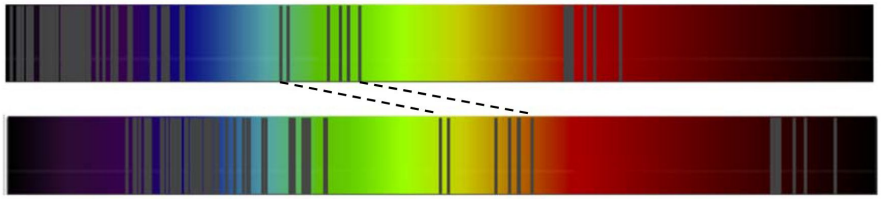




Fossils & Earth's past surface

Availability of freshwater resources





Origin of the universe

Learn more about the MEL/baMEL and how to use them in open-access issues of *The Earth Scientist*

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The Salt Ponds of San Francisco Bay. © Charles Benton, UC Berkeley Photo Date: September 2005 Courtesy: National Science Foundation

INSIDE THIS ISSUE

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The Andromeda Galaxy and one of its satellite galaxies, M32. Image by Ardis Herrold.

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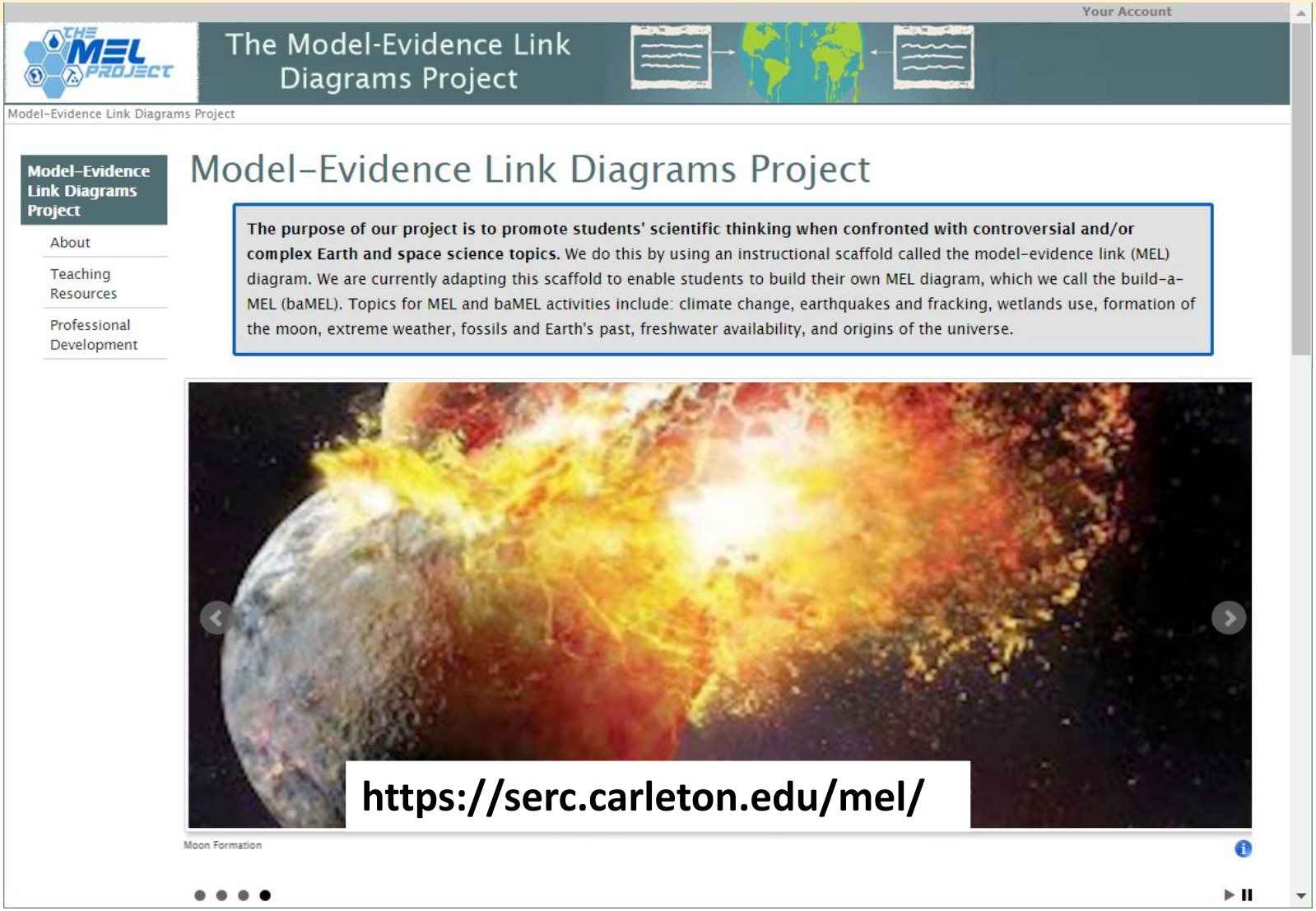
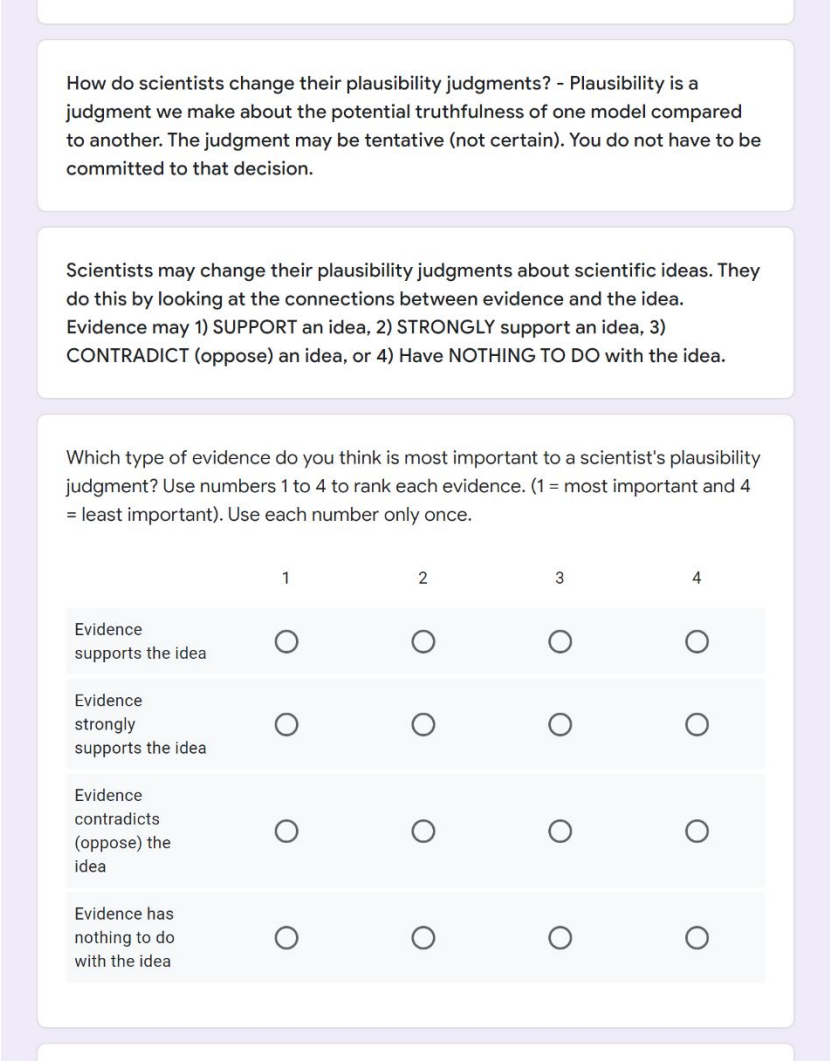
Please visit the MEL project website for free access to all our instructional materials and resources



Virtual MELs in Development!

First test of the virtual Fracking MEL in classrooms happened *this week!*

Watch our website for future releases



How do scientists change their plausibility judgments? - Plausibility is a judgment we make about the potential truthfulness of one model compared to another. The judgment may be tentative (not certain). You do not have to be committed to that decision.

Scientists may change their plausibility judgments about scientific ideas. They do this by looking at the connections between evidence and the idea. Evidence may 1) SUPPORT an idea, 2) STRONGLY support an idea, 3) CONTRADICT (oppose) an idea, or 4) Have NOTHING TO DO with the idea.

Which type of evidence do you think is most important to a scientist's plausibility judgment? Use numbers 1 to 4 to rank each evidence. (1 = most important and 4 = least important). Use each number only once.

	1	2	3	4
Evidence supports the idea	○	○	○	○
Evidence strongly supports the idea	○	○	○	○
Evidence contradicts (oppose) the idea	○	○	○	○
Evidence has nothing to do with the idea	○	○	○	○

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Questions & Comments?

Thanks so much for attending!

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