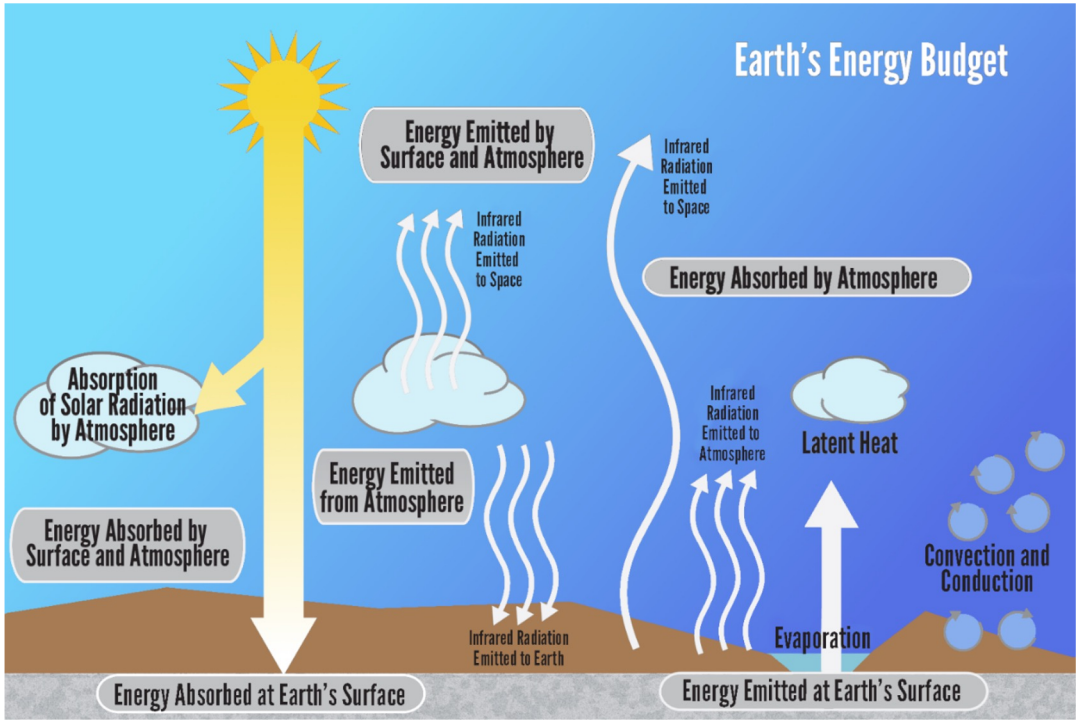
Promoting Argument-Driven Explanation in Earth & Environmental Science

Dr. Donna Governor, UNG
Dr. Lorraine Ramirez Villarin, UNG
Dr. Missy Holzer, Chatham HS, retired



THE LR MEL PROJECT

NSTA 2024 Denver

Friday, March 22

8:00 AM - 9:00 AM

Colorado Convention Center - Mile High Ballroom 4C

SLRG Science Learning Research Group · University of Maryland 1856 · Temple University · UNG University of North Georgia · USC Rossier School of Education · National Science Teaching Institute · Institute for Global Environmental Strategies

NSF

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Issues in Earth/Environmental Education

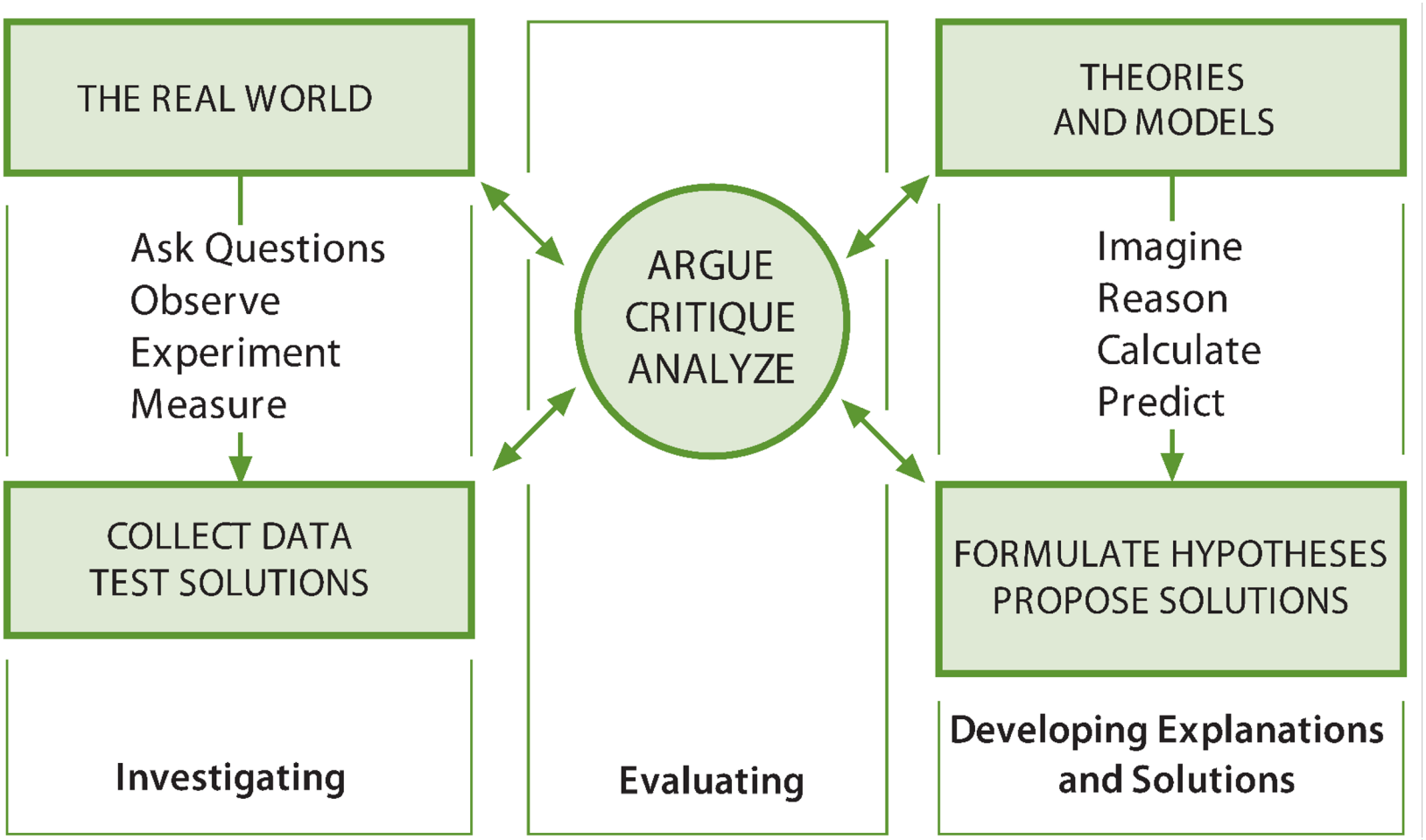
Controversial topics of socioscientific relevance:

- Climate change
- Fracking
- Extreme Weather
- Freshwater Resources
- Origins of the Universe

Teaching the science alone isn't enough…. We must do more.

If we want to improve scientific literacy, how do we get students to think critically about evidence and make scientific judgments?

Scientific literacy involves 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)

NGSS/3D Framework Applications

Science & Engineering Practices:

- Engaging in Argument from Evidence
  - Argumentation is seen as essential to scientific discourse because it provides a framework for students to make claims supported by evidence and reasoning related to scientific theory
    - ➢ Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education*, *84*(3), 287-312. doi:10.1002/(SICI)1098-237X

3D Framework Applications

Cross Cutting Concepts:

- Cause & Effect
  - Cause and effect relationships may be used to predict phenomena in natural or designed systems.
  - Changes in systems may have various causes that may not have equal effects.

Familiar Instructional Strategies

Claim-Evidence-Reasoning

- 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

Claims vs. 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

EVIDENCE is the foundation for both claims and models!

More about Models

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 the causes and effects of a particular phenomenon and its systematic relationships.

➢ National Research Council [NRC]. (2012). A framework for K-12 science education: Practices, crosscutting concepts, and core ideas. Washington, DC: The National Academies Press.

<u>More than one model may be an acceptable explanation</u> for the same phenomenon. It is not always possible to exclude all but one model – and also not always desirable. *(ex: Dual wave/particle nature of light.)*

➢ National Center for Improving Student Learning and Achievement in Mathematics and Science, (2018). Explanatory Models in Science. http://ncisla.wceruw.org/muse/models/index.pdf Accessed 5/22/18

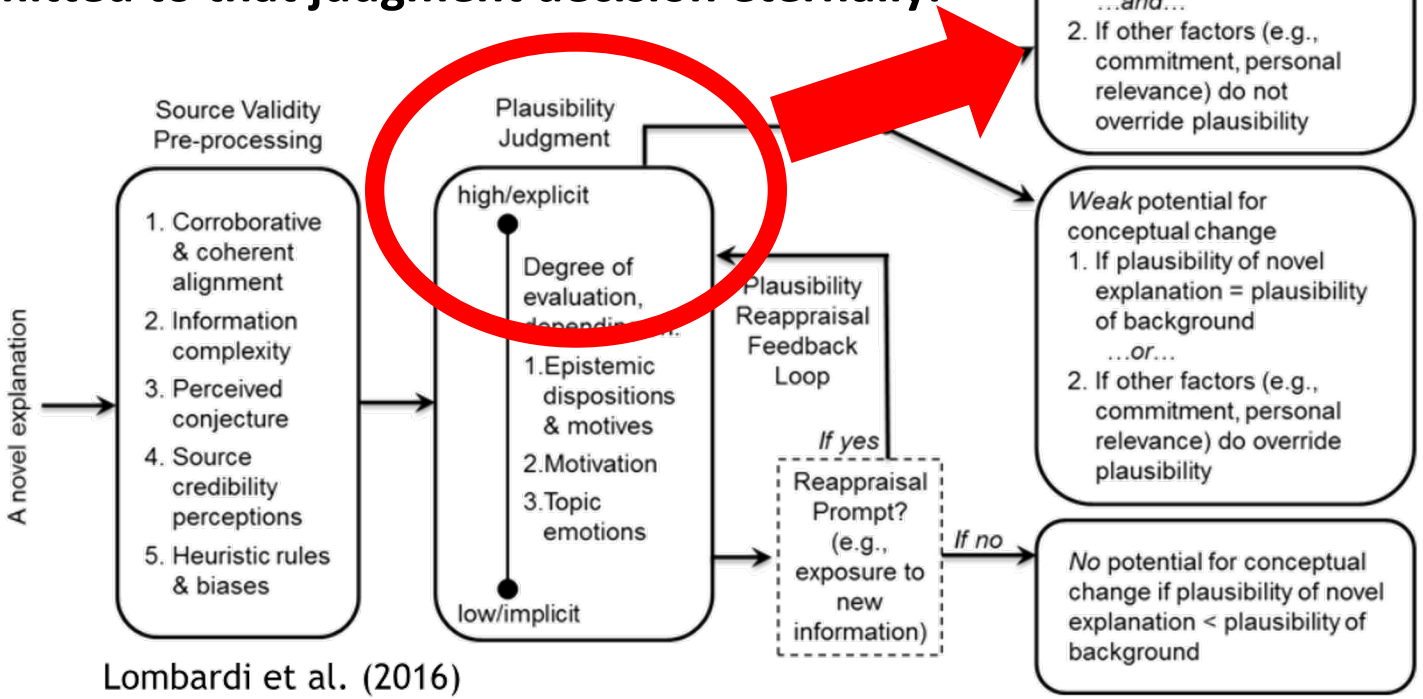
How are scientific models evaluated?

What is Plausibility?

Plausibility is the judgment we make about the truthfulness - or the potential truthfulness - of one model or option compared to another.

The judgment may be tentative, and you do not have to be committed to that judgment decision eternally.

Scientists may change - and do change - their plausibility judgments about scientific ideas.

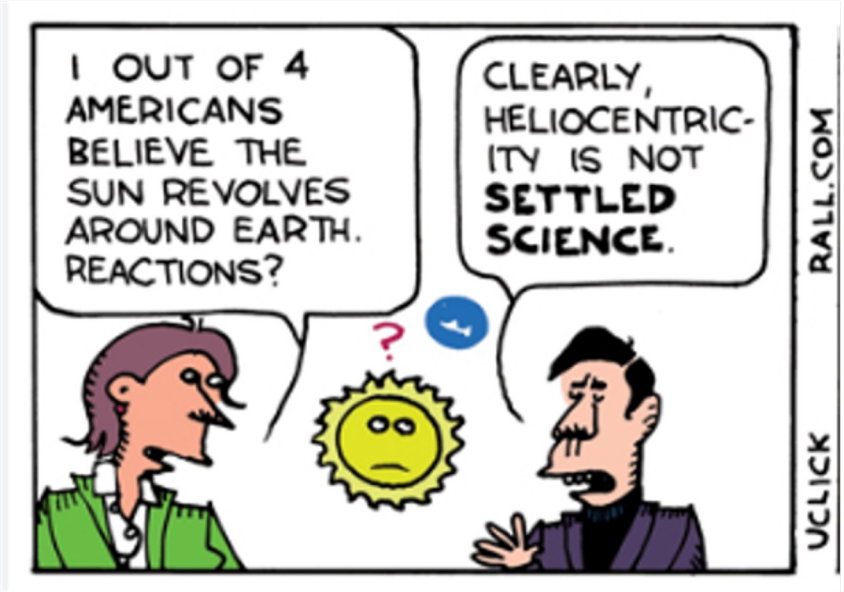


Lombardi et al. (2016)

The Role of Falsifiability in Plausibility Judgements

Scientific ideas must be FALSIFIABLE…

- 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 (arguably most important) when evaluating scientific knowledge.



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)

Begin by 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	

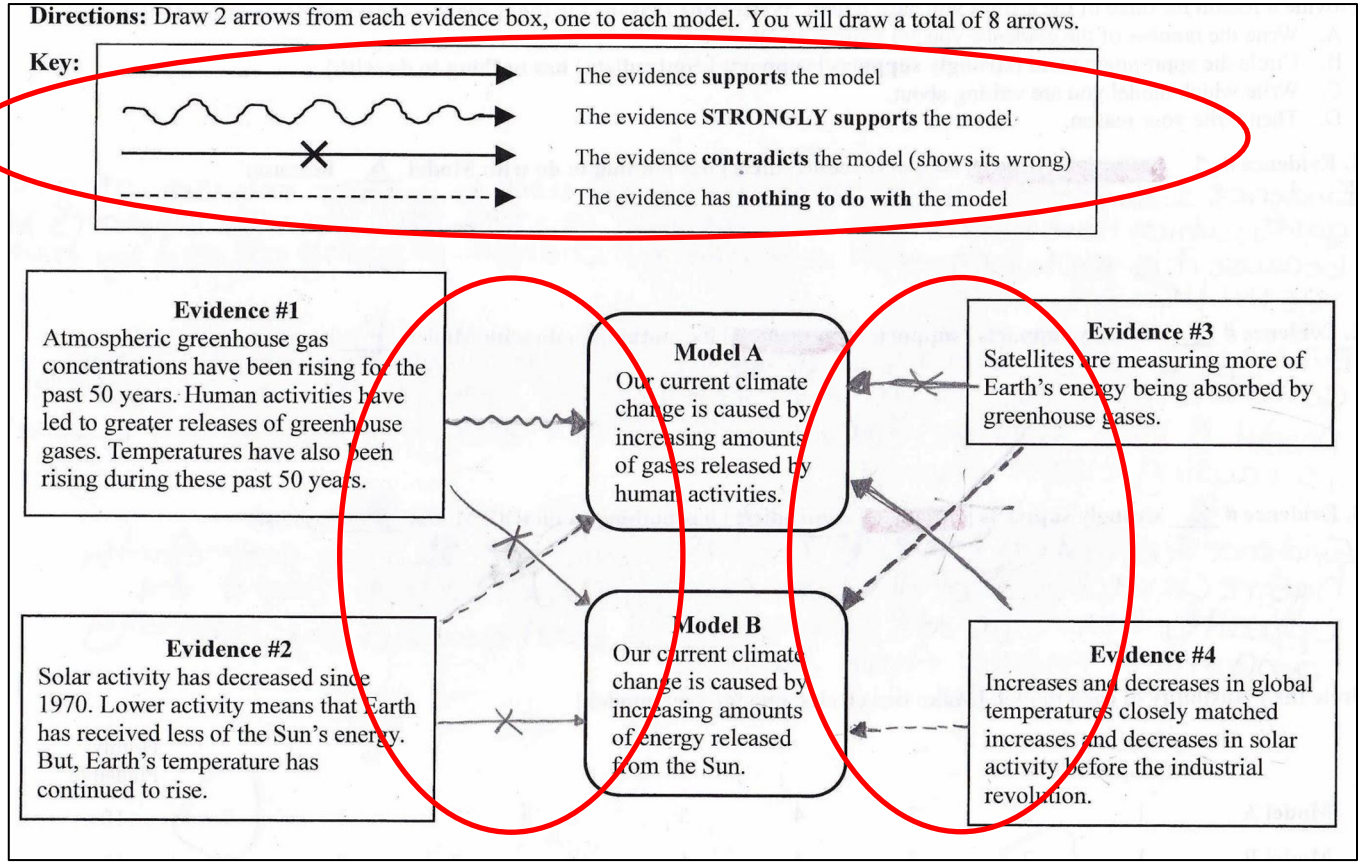
Plausibility Ranking Task (PRT; 2017-10-11) *Page 2 of 2*

The Plausibility Ranking Task

Core Activity:
The Model-Evidence Link Diagram

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

Chinn & colleagues (2012, 2014)

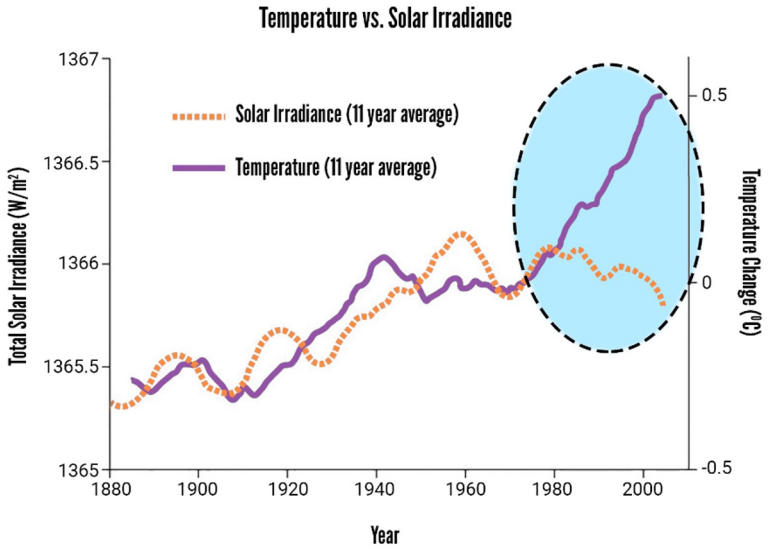


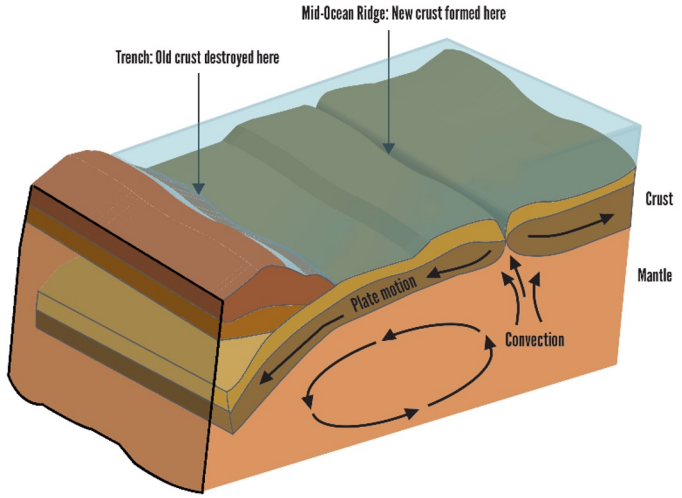
Example of student completed Model-Evidence Link (MEL) diagram

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

All MELs are developed to cover concepts in geology, hydrology, climate, and astronomy including…

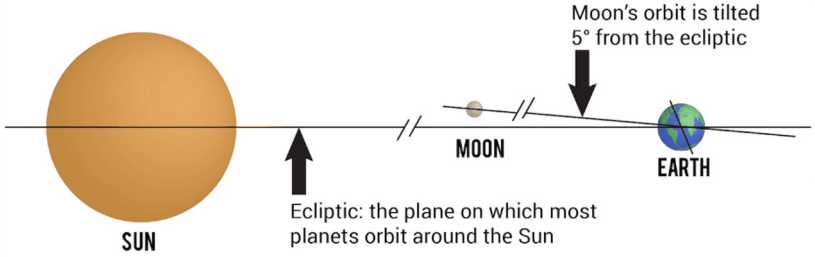
Causes of current climate change

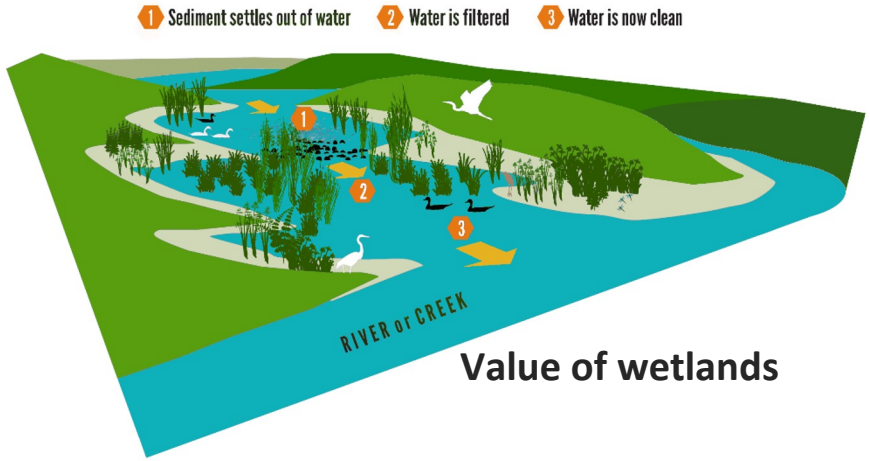




Hydraulic fracturing & earthquakes

Formation of the Earth's Moon





Value of wetlands

MEL Step 1: Rating Plausibility

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

Please complete this sheet and feel free to work with a neighbor

Rate Plausibility of Each Model:

- Model A: Climate change is caused by humans who are releasing gases into the atmosphere
- Model B: Climate change is caused by increasing amounts of energy released from the Sun

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

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.

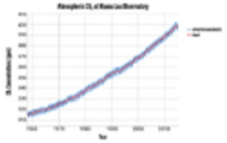


Figure 1. Carbon dioxide levels in the atmosphere. Credit: Wright Senseni

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.

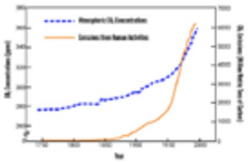


Figure 2. CO_2 released by human activities. Credit: Wright Senseni

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.

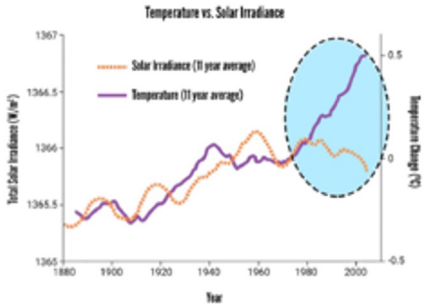


Figure 1. Solar activity levels over time. Credit: Wright Senseni

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.

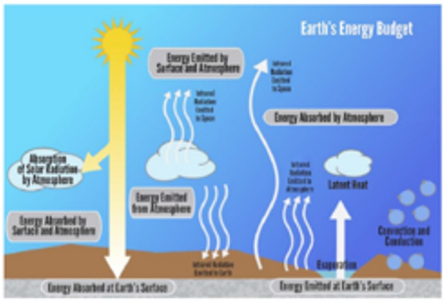


Figure 1. Earth's energy budget. Credit: Wright Senseni

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.

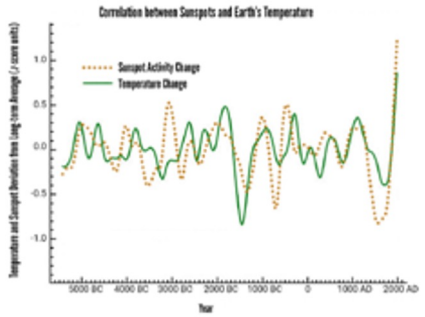


Figure 1. Sunspot activity and temperature over time. Credit: Wright Senseni

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: Connecting Evidence to Models

Complete the MEL diagram using the evidence texts as a resource

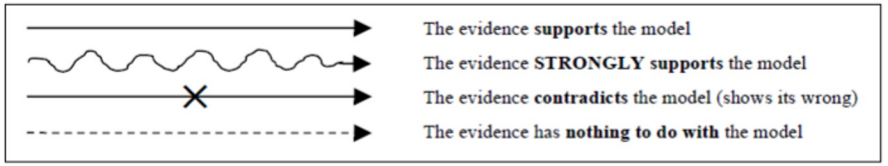
Role of Argumentation & Negotiation

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:



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.

Please complete the diagram and feel free to work with a neighbor

MEL Step 4:
Model Re-Evaluation & Explanation

Explain your reasoning

Re-evaluate the Models using Evidence-based reasoning

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

Please work on this individually.

Provide a reason for three of the arrows you have drawn. **Write your reasons for the three most interesting or important arrows.**

A. Write the number of the evidence you are writing about.
B. Circle the appropriate word (**strongly supports | supports | contradicts | has nothing to do with**).
C. Write which model you are writing about.
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:

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

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

Evaluating the Explanation Task

Provide a reason for three of the arrows you have drawn. **Write your reasons for the three most interesting or important arrows.**

A. Write the number of the evidence you are writing about.
B. Circle the appropriate word (**strongly supports | supports | contradicts | has nothing to do with**).
C. Write which model you are writing about.
D. Then write your reason.

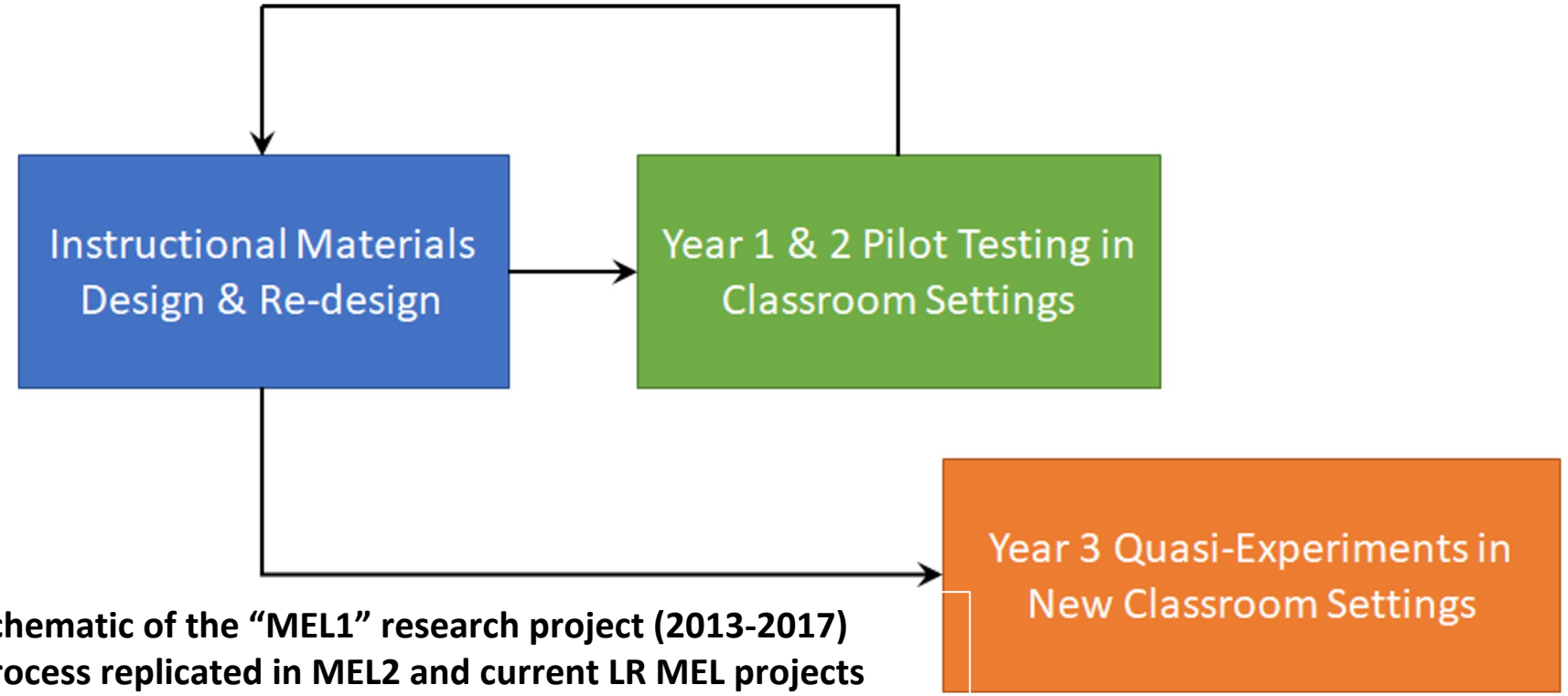
1. Evidence # 1 **strongly supports | supports | contradicts | has nothing to do with Model** A **because:**
Evidence 1 says that human activities have lead to greater releases of greenhouse gases, which have been rising for the past 50 years. This strongly supports Model A because it is explaining that our climate change is being caused by human activities.

2. Evidence # 1 **strongly supports | supports | contradicts | has nothing to do with Model** B **because:**
Evidence 1 contradict Model B, because evidence one says that human activities have lead to greater releases of greenhouse gases, while model B says that increasing amounts of energy from the sun is what is causing climate change.

3. Evidence # 2 **strongly supports | ~~supports~~ | contradicts | has nothing to do with Model** B **because:**
Evidence 2 contridicts Model B because evidence 2 says that Earth has recieved less of the suns energy, and mode B says the opposite, that Climate change has been caused by increasing amounts of energy from the sun.

Evaluate students claims using evidence-based reasoning

Research Process: Investigating Students' evaluations, plausibility & understanding of Earth & Environmental Science Topics



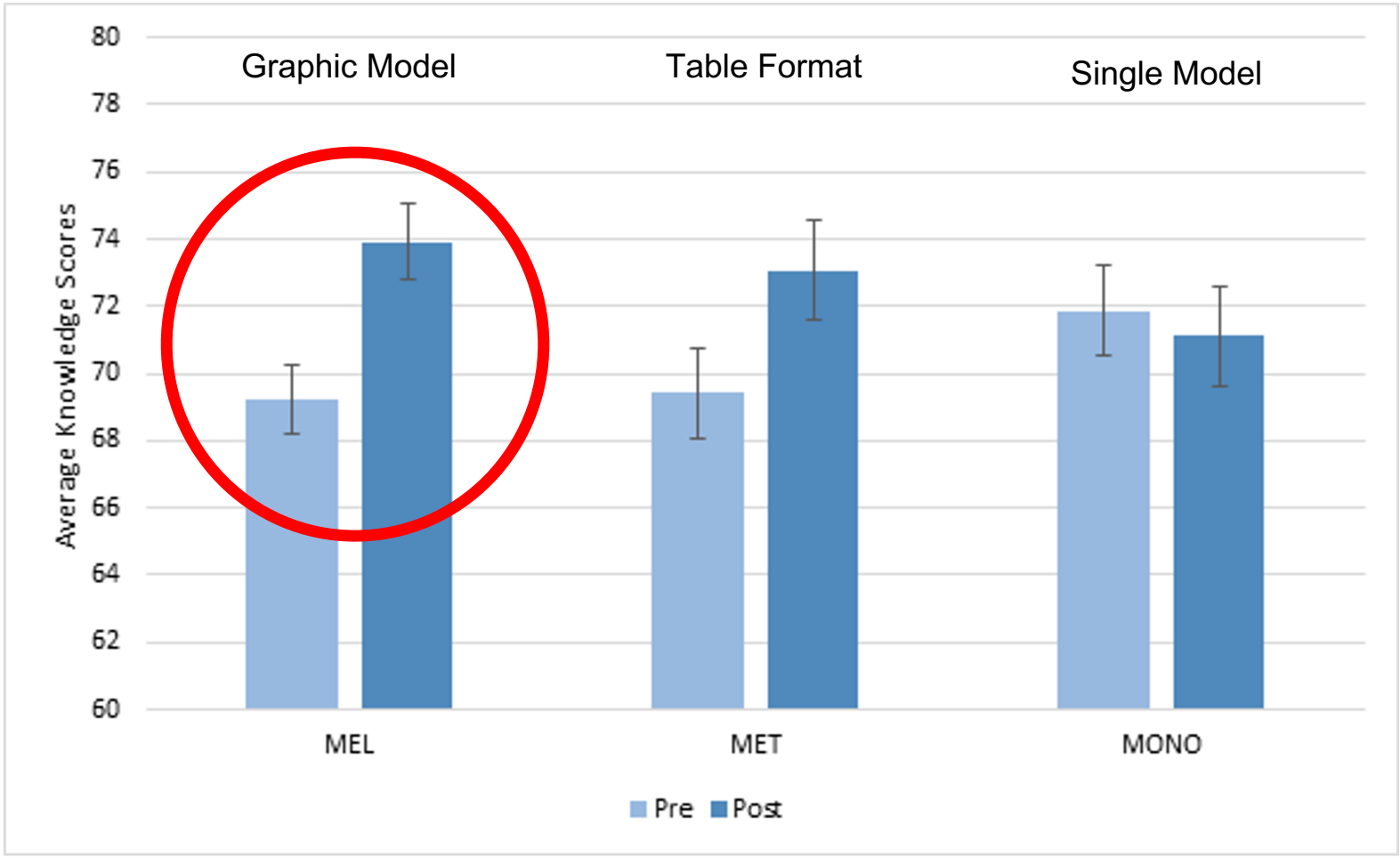
Schematic of the "MEL1" research project (2013-2017)
Process replicated in MEL2 and current LR MEL projects

Research focus:

- ***Student learning***
- ***Argumentation***
- ***Shifts in Plausibility - understanding scientific models and evidence***

Explanations Deepen Student Learning!

The MEL activities result in ~1 letter grade increase in knowledge



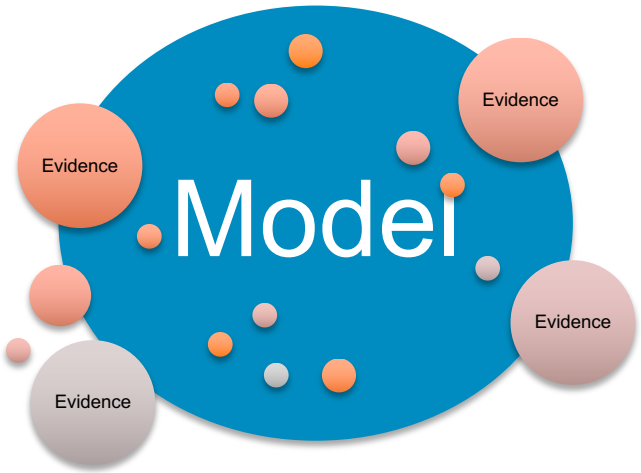
Our research shows that students make scientific evaluations and learn about these topics more deeply

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

pcMELs vs. baMELs

pcMELs

- Two models
- Four lines of evidence



baMELS

- Three models
- Eight (or more) lines of evidence

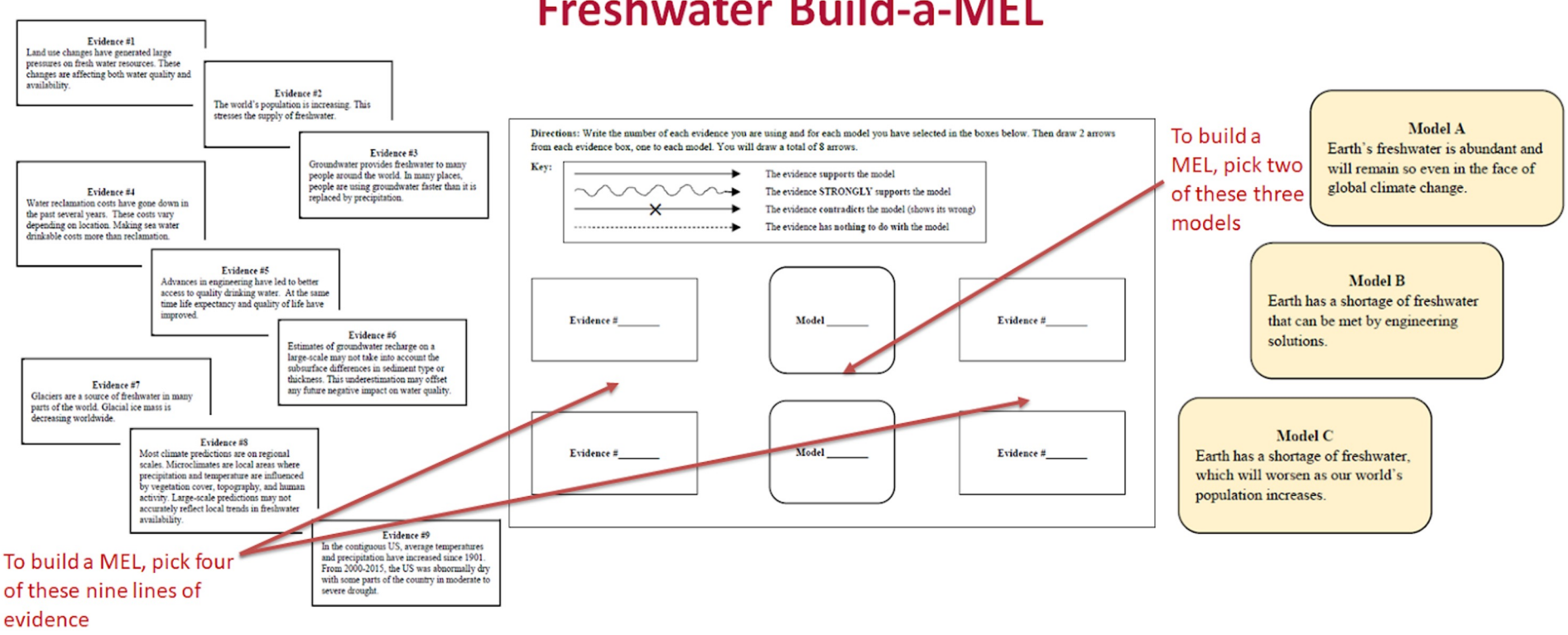
All baMELs have a pcMEL version

baMELs: Topics

- Topics:
  - Fossils
  - Origins
  - Extreme Wx
  - Freshwater

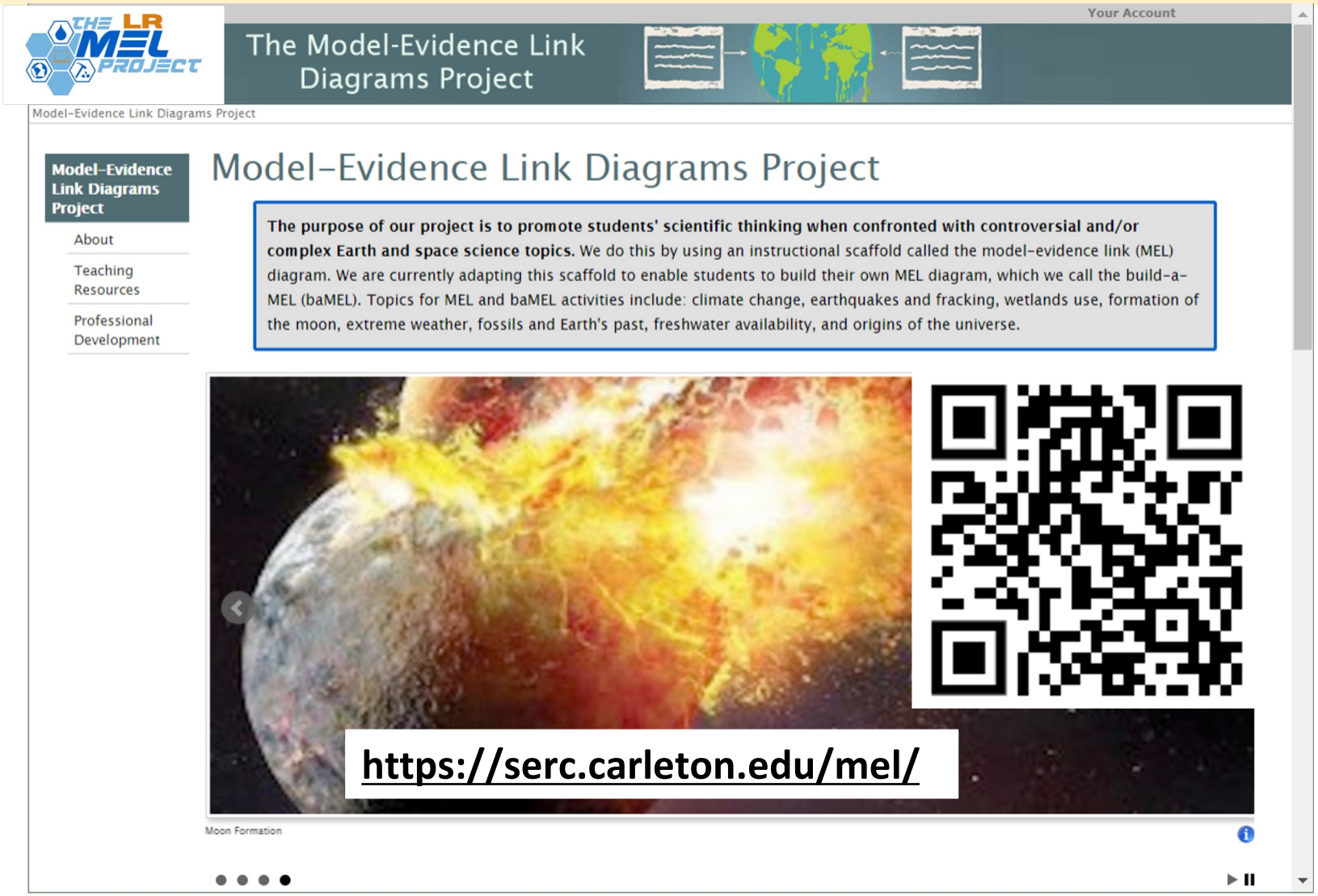
Try some of these out!

baMELs: Scaffolds that Increase Students' "conceptual agency"

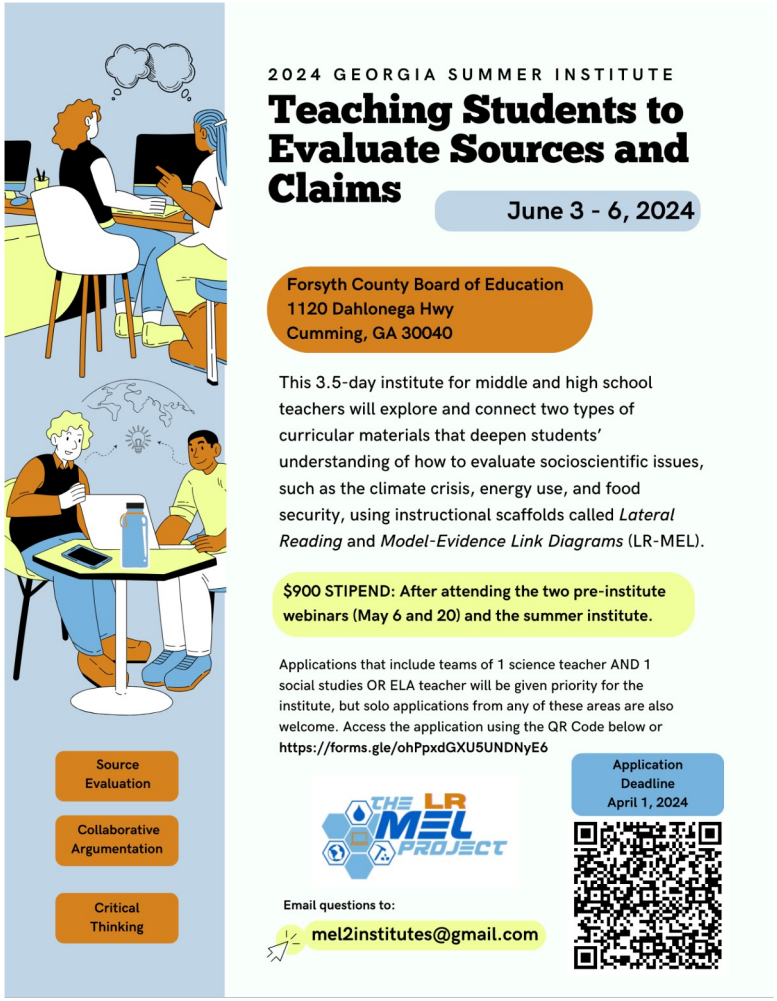


Students who exercise conceptual agency are authors of their own contributions, accountable to the classroom learning community, and have the authority to think about and solve problems (Nussbaum & Asterhan, 2016)

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



New Project!
Integrating Lateral Reading Strategies for Understanding Socioscientific Issues



Teams of 2 Teachers:

- Science + ELA or SS

Forsyth County Georgia

- June 3-6, 2024

Philadelphia, PA

- June 24-27, 2024

Stipends:

- $900 each
- Additional compensation for follow up seminar

Questions & Comments?

Thanks so much for attending!

Please visit us at
https://serc.carleton.edu/mel/

Donna Governor

- Donna.governor@ung.edu

Lorraine Ramirez Villarin

- Lorraine.RamirezVillarin@ung.edu

Missy Holzer

- missy.holzer@gmail.com

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