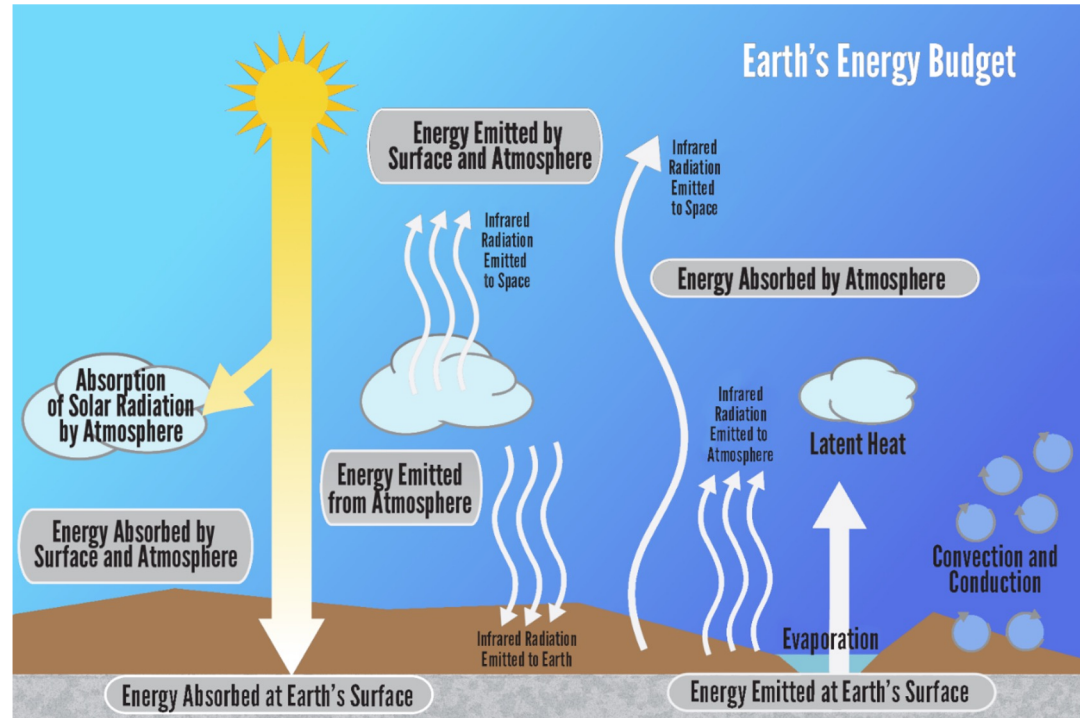


Promoting Argument-Driven Explanation in Earth & Environmental Science

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UNG

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Villarin, UNG

Dr. Missy Holzer,
Chatham HS, retired



NSTA 2024 Denver

Friday, March 22

8:00 AM - 9:00 AM

Colorado Convention Center -
Mile High Ballroom 4C



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Issues in Earth/Environmental Education

Controversial topics of socioscientific relevance:

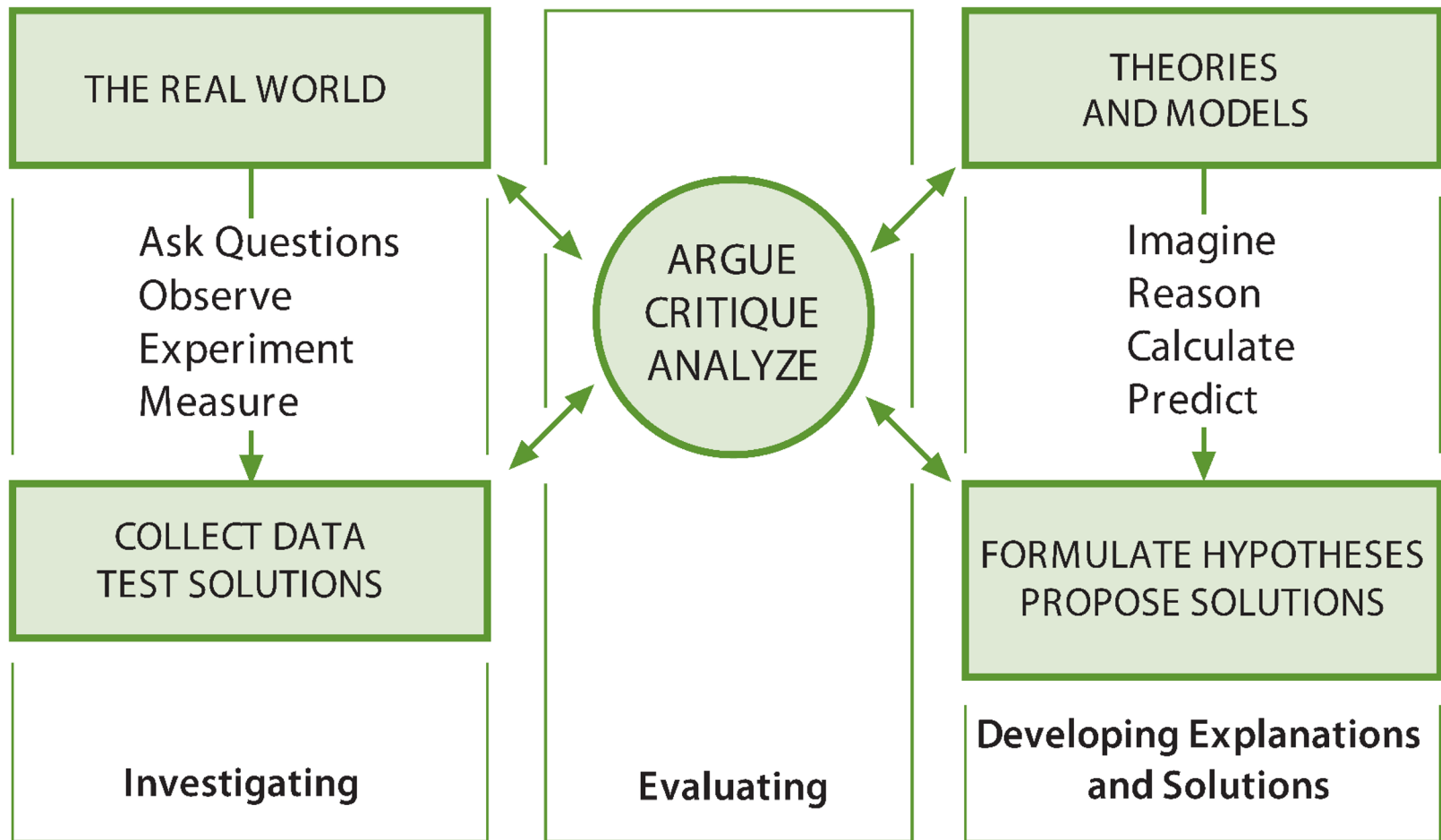
- Climate change
- Fracking
- Extreme Weather
- Freshwater Resources
- Origins of the Universe

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. Models must be coordinated with lines of evidence 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.

More than one model may be an acceptable explanation 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?

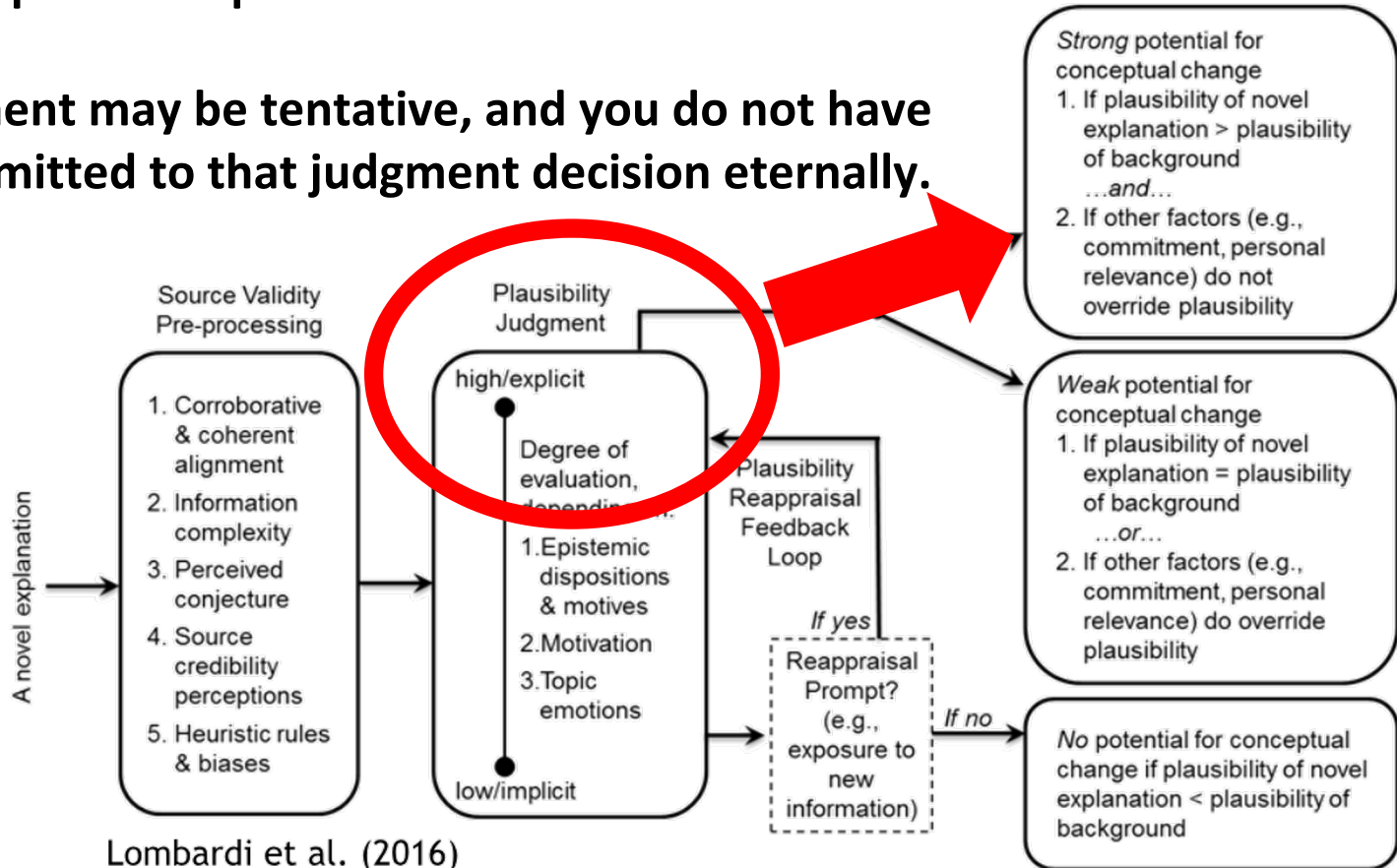
What is Plausibility?

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.



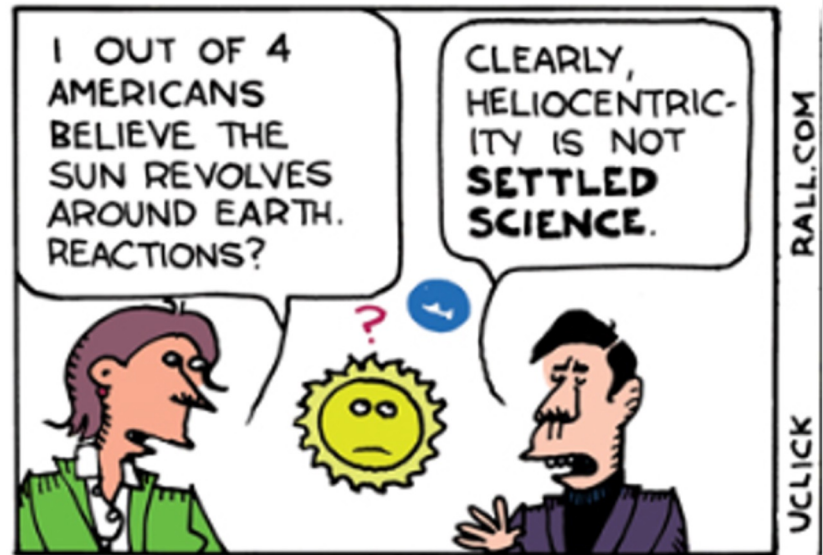
Scientists may change - and do change - their plausibility judgments about scientific ideas.



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

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.

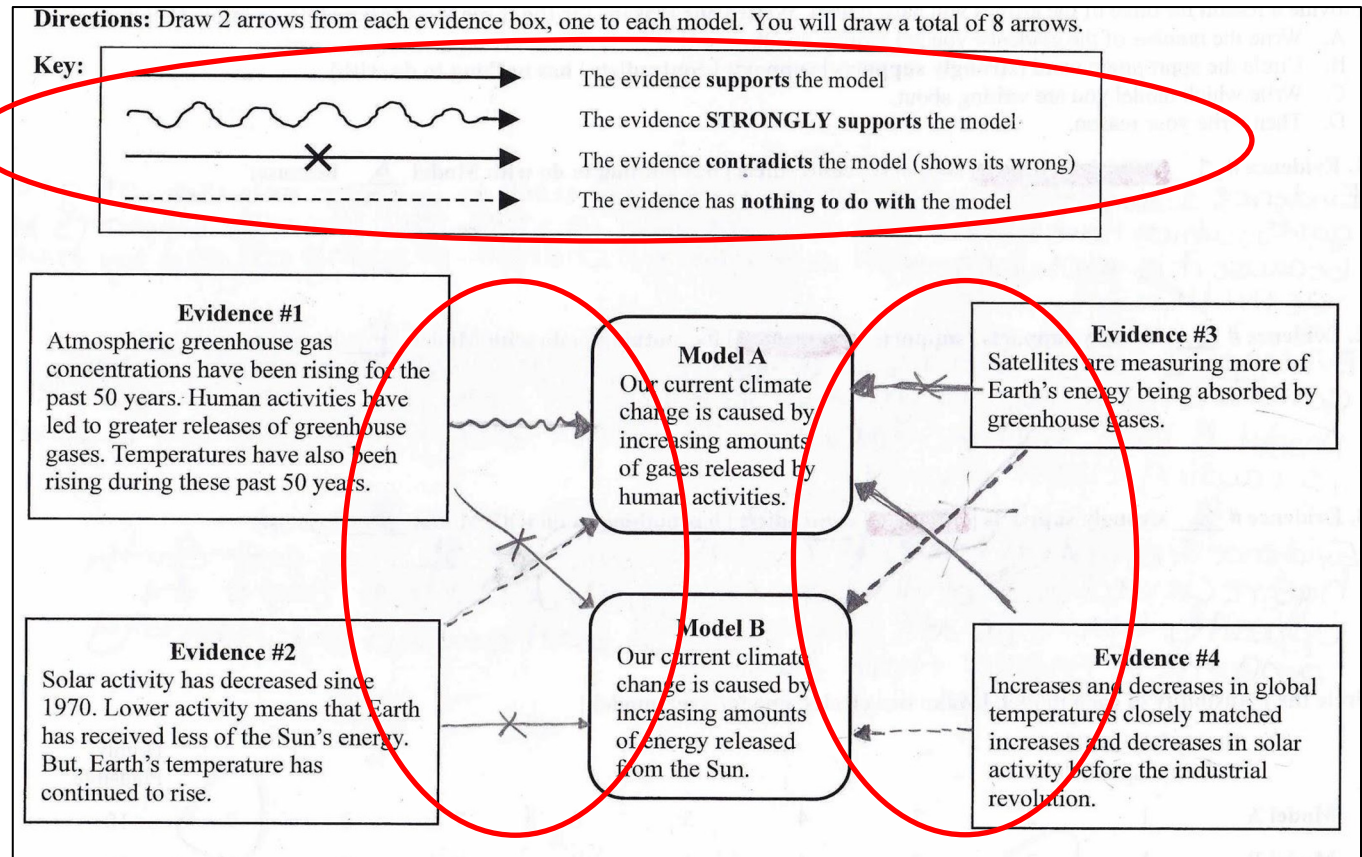
Type of evidence	Your ranking
Evidence supports the idea	
Evidence strongly supports the idea	
Evidence contradicts (opposes) the idea	
Evidence has nothing to do with the idea	

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)

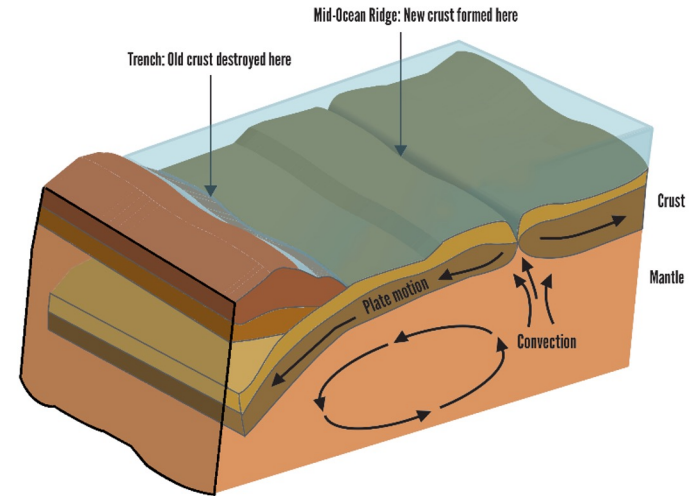
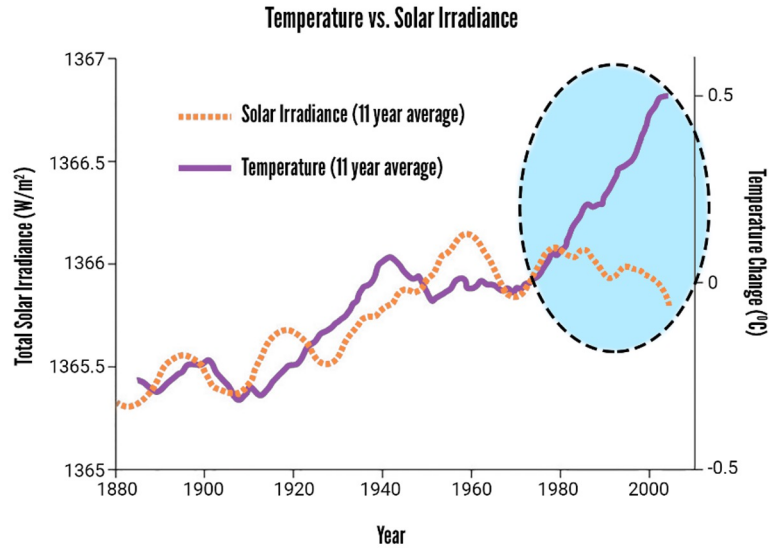


Example of student completed Model-Evidence Link (MEL) diagram

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

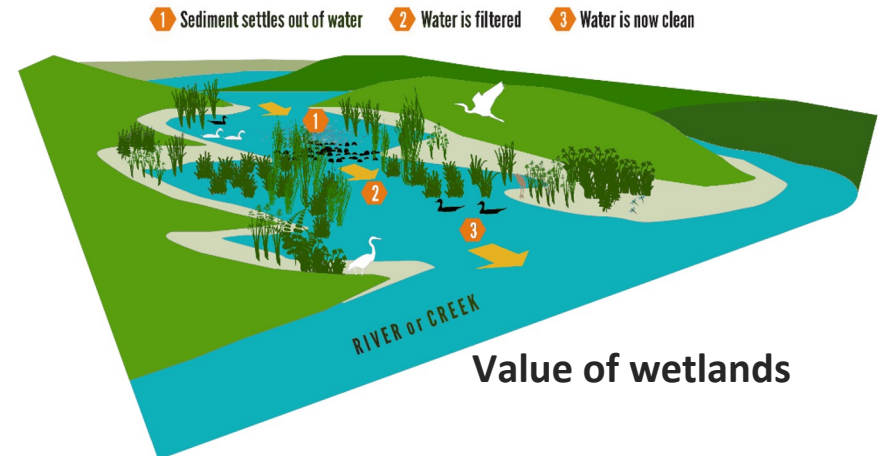
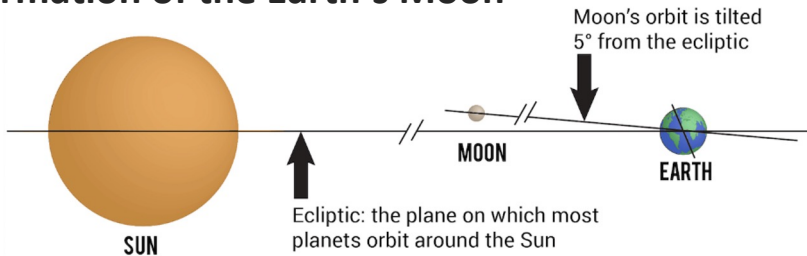
All MELs are developed to cover concepts in geology, hydrology, climate, and astronomy including...

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.]

	1	2	3	4	5	6	7	8	9	10
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.

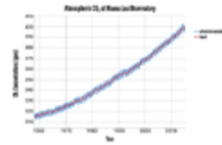


Figure 1: Carbon dioxide levels in the atmosphere. Credit: Wright Science. The symbol for carbon dioxide is CO₂. These levels have been increasing (Figure 1). CO₂ in the atmosphere absorbs infrared energy emitted by Earth. People call CO₂ a greenhouse gas because it keeps some of Earth's energy from escaping to space.

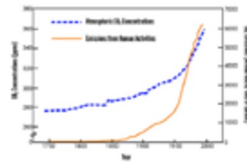


Figure 2: CO₂ released by human activities. Credit: Wright Science. Figure 2 shows increasing releases of CO₂ by the human activity of burning fossil fuels, including coal, gasoline, natural gas, and wood. Burning fossil fuels releases CO₂ into the atmosphere.

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

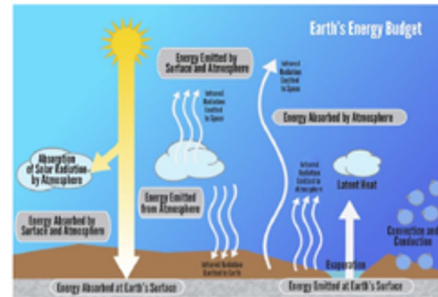


Figure 1: Earth's energy budget. Credit: Wright Science. Figure 1 above shows Earth's energy budget. Earth absorbs about half of the Sun's energy. Most of the Sun's energy comes to Earth as visible light. Earth radiates this absorbed energy as invisible light called infrared. Some of this infrared energy 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 #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.

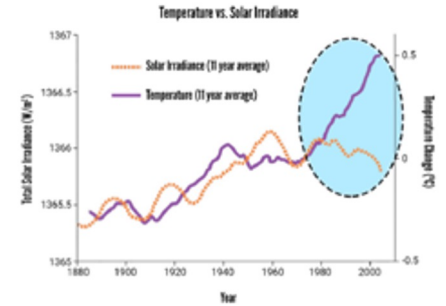


Figure 1: Solar activity levels over time. Credit: Wright Science. The Sun's brightness is one way to measure solar activity. In Figure 1, the dashed line shows the Sun's brightness. Since 1970, the Sun's brightness has been decreasing. The solid line on the graph shows Earth's temperature. The graph 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 #4: Increases and decreases in global temperatures closely matched increases and decreases in solar activity before the industrial revolution.

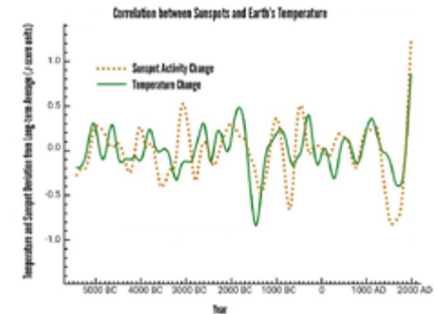


Figure 1: Sunspot activity and temperature over time. Credit: Wright Science. In Figure 1, sunspot activity is the dashed line. Solar activity increases when the Sun has more sunspots. The solid line shows temperature. The shapes of the sunspot and temperature curves match closely. Peaks in the temperature 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 tree 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:

	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.

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

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

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

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.

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

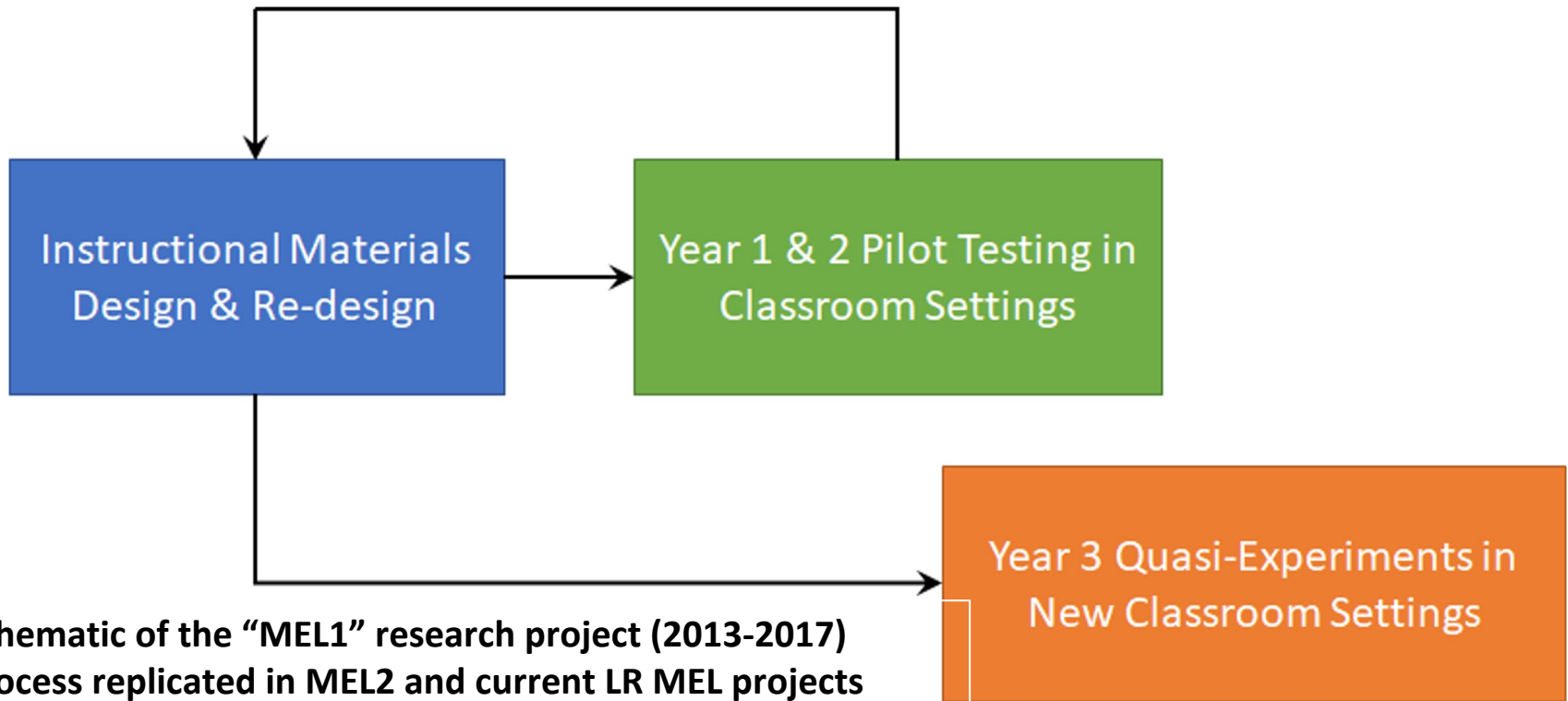
Evidence 1 contradicts Model B because evidence one says that human activities have led to greater releases of greenhouse gases, while model B says that increasing amounts of energy from the sun is what is causing climate change.

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

Evidence 2 contradicts Model B because evidence 2 says that Earth has received less of the sun's energy, and model 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

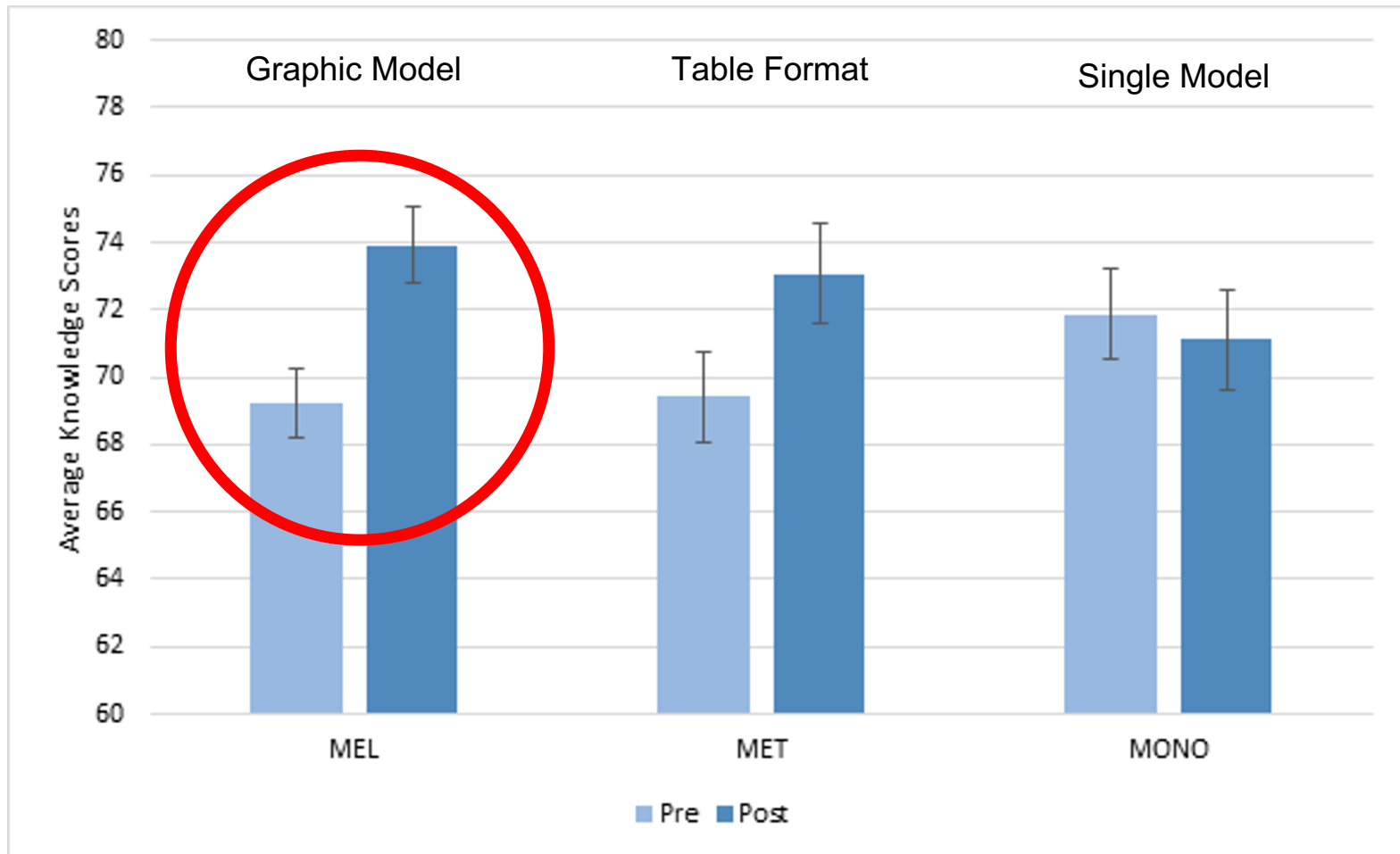


Research focus:

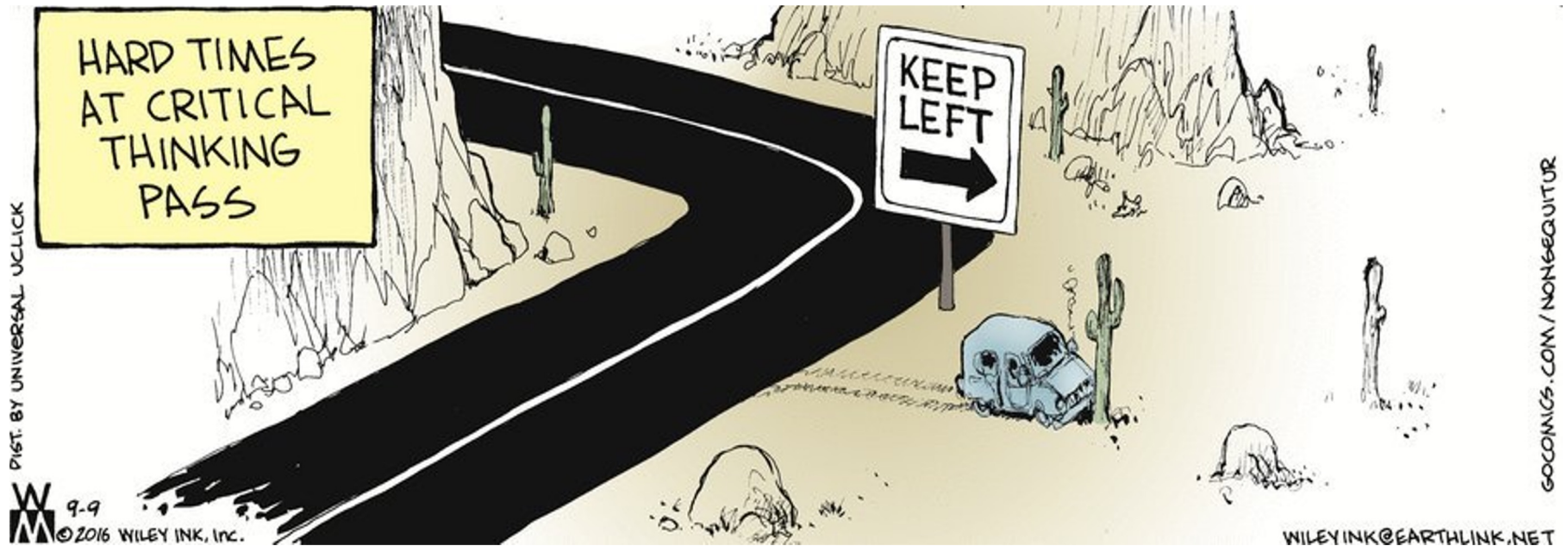
- ***Student learning***
- ***Argumentation***
- ***Shifts in Plausibility - understanding scientific models and evidence***

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



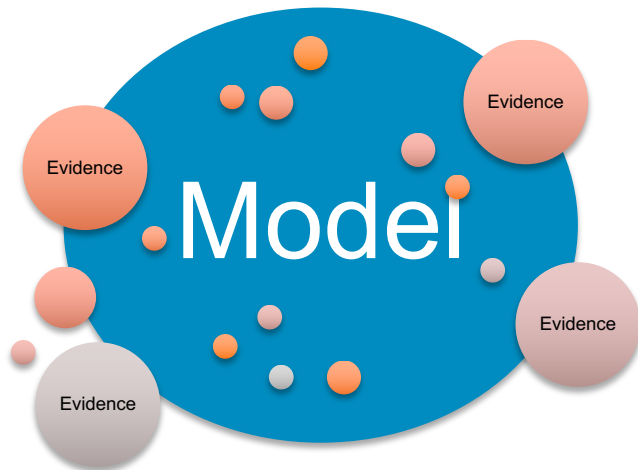
But we were unsatisfied, because some students were not transferring their evaluative thinking outside of the classroom context



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"

Freshwater Build-a-MEL

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

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 replaced by precipitation.

Evidence #4
Water reclamation costs have gone down in the past several years. These costs vary depending on location. Making sea water drinkable costs more than reclamation.

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 improved.

Evidence #6
Estimates of groundwater recharge on a large-scale may not take into account the subsurface differences in sediment type or thickness. This underestimation may offset any future negative impact on water quality.

Evidence #7
Glaciers are a source of freshwater in many parts of the world. Glacial ice mass is decreasing worldwide.

Evidence #8
Most climate predictions are on regional scales. Microclimates are local areas where precipitation and temperature are influenced by vegetation cover, topography, and human activity. Large-scale predictions may not accurately reflect local trends in freshwater availability.

Evidence #9
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.

Directions: Write the number of each evidence you are using and for each model you have selected in the boxes below. Then 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

Model A
Earth's freshwater is abundant and will remain so even in the face of global climate change.

Model B
Earth has a shortage of freshwater that can be met by engineering solutions.

Model C
Earth has a shortage of freshwater, which will worsen as our world's population increases.

To build a MEL, pick four of these nine lines of evidence

To build a MEL, pick two of these three models

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



The Model-Evidence Link Diagrams Project



Your Account

Model-Evidence Link Diagrams Project

Model-Evidence Link Diagrams Project

About

Teaching Resources

Professional Development

Model-Evidence Link Diagrams Project

The purpose of our project is to promote students' scientific thinking when confronted with controversial and/or complex Earth and space science topics. We do this by using an instructional scaffold called the model-evidence link (MEL) diagram. We are currently adapting this scaffold to enable students to build their own MEL diagram, which we call the build-a-MEL (baMEL). Topics for MEL and baMEL activities include: climate change, earthquakes and fracking, wetlands use, formation of the moon, extreme weather, fossils and Earth's past, freshwater availability, and origins of the universe.



<https://serc.carleton.edu/mel/>

Moon Formation



New Project!

Integrating Lateral Reading Strategies for Understanding Socioscientific Issues



2024 GEORGIA SUMMER INSTITUTE

Teaching Students to Evaluate Sources and Claims

June 3 - 6, 2024

Forsyth County Board of Education
1120 Dahlonega Hwy
Cumming, GA 30040

This 3.5-day institute for middle and high school teachers will explore and connect two types of curricular materials that deepen students' understanding of how to evaluate socioscientific issues, such as the climate crisis, energy use, and food security, using instructional scaffolds called *Lateral Reading* and *Model-Evidence Link Diagrams* (LR-MEL).

\$900 STIPEND: After attending the two pre-institute webinars (May 6 and 20) and the summer institute.

Applications that include teams of 1 science teacher AND 1 social studies OR ELA teacher will be given priority for the institute, but solo applications from any of these areas are also welcome. Access the application using the QR Code below or <https://forms.gle/ohPpxdGXU5UNDNyE6>

Source Evaluation

Collaborative Argumentation

Critical Thinking



Email questions to:

mel2institutes@gmail.com

Application
Deadline
April 1, 2024



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/>

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Missy Holzer

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