Cultivating climate change literacy through scaffolded critique and evaluation

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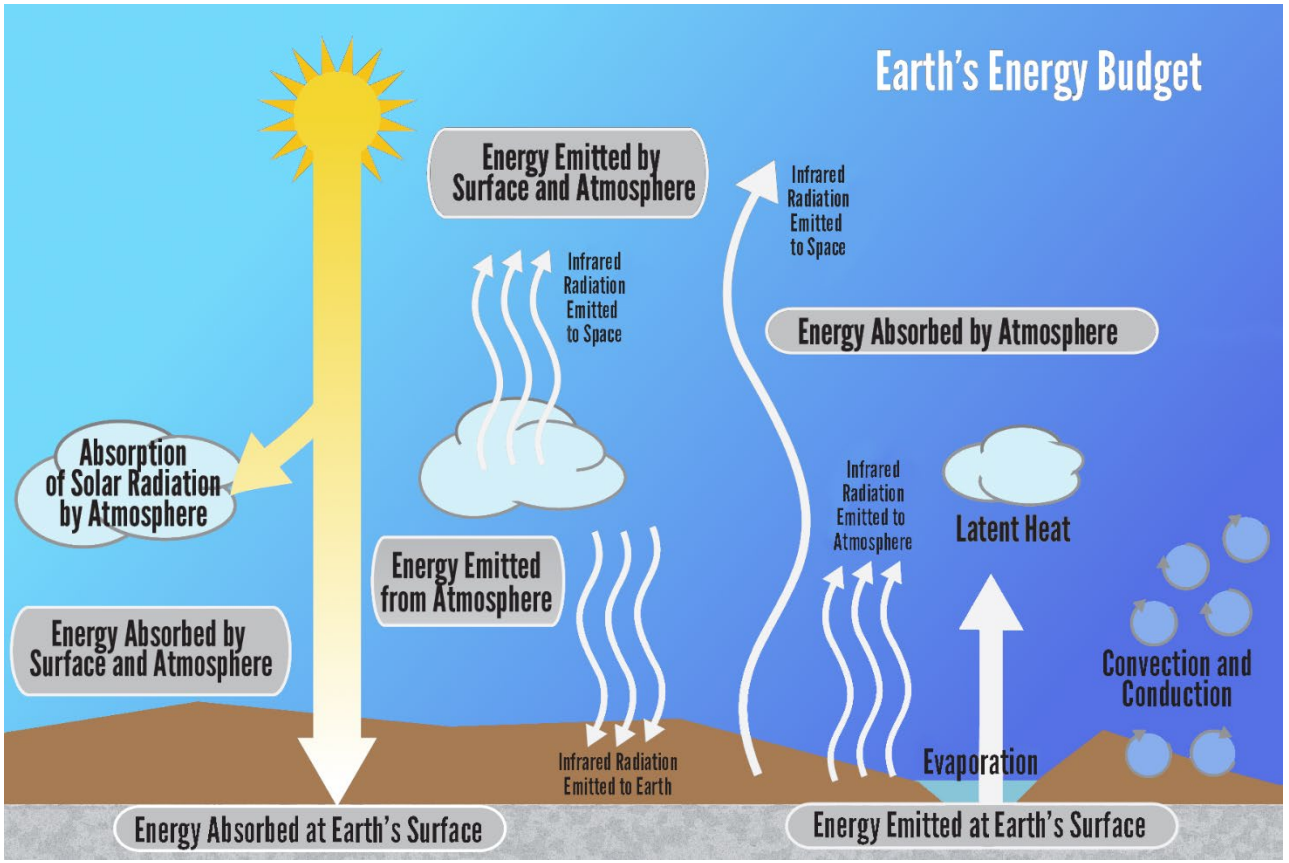

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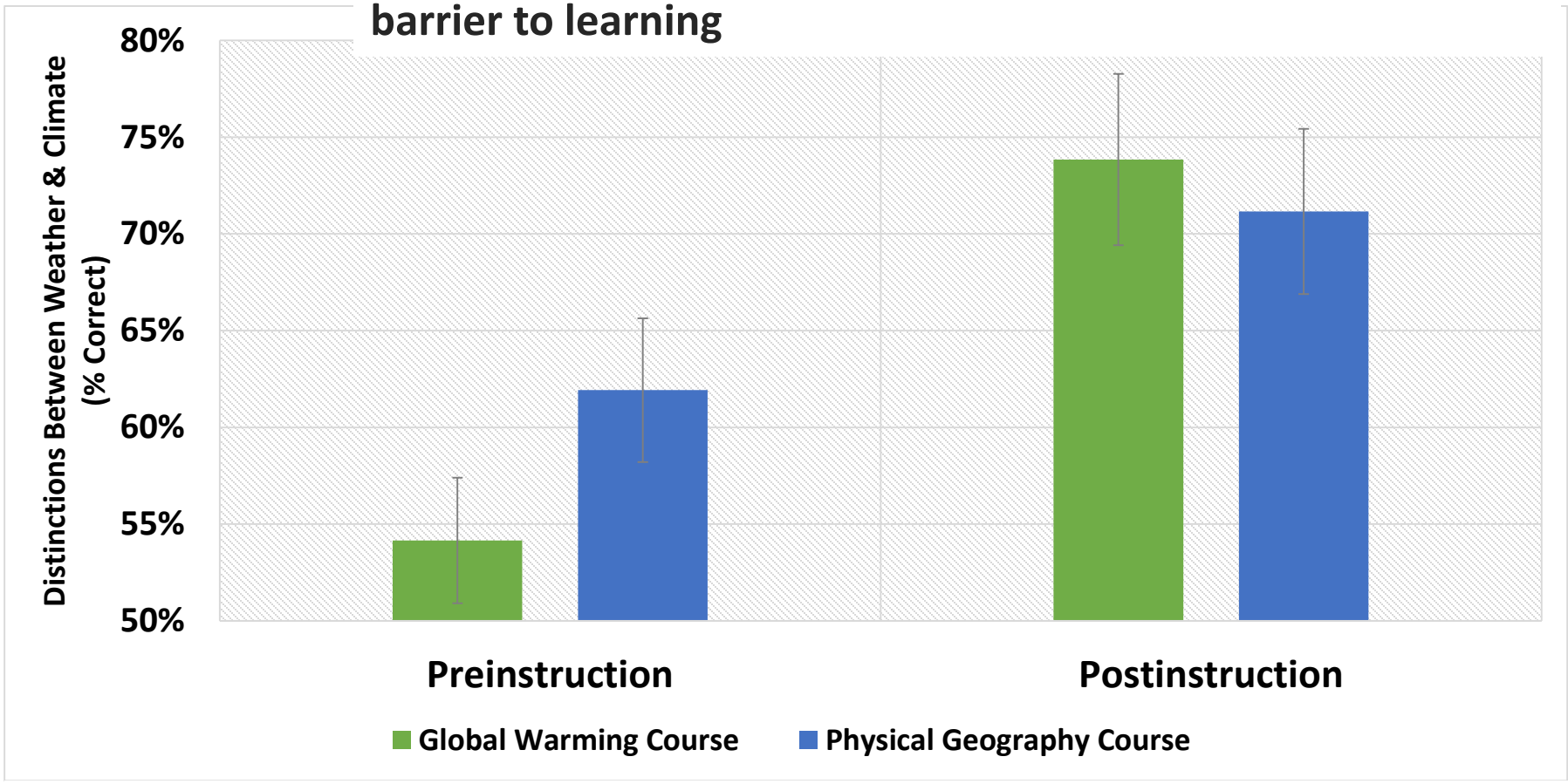
Students' knowledge may be different than scientifically accurate conceptions…

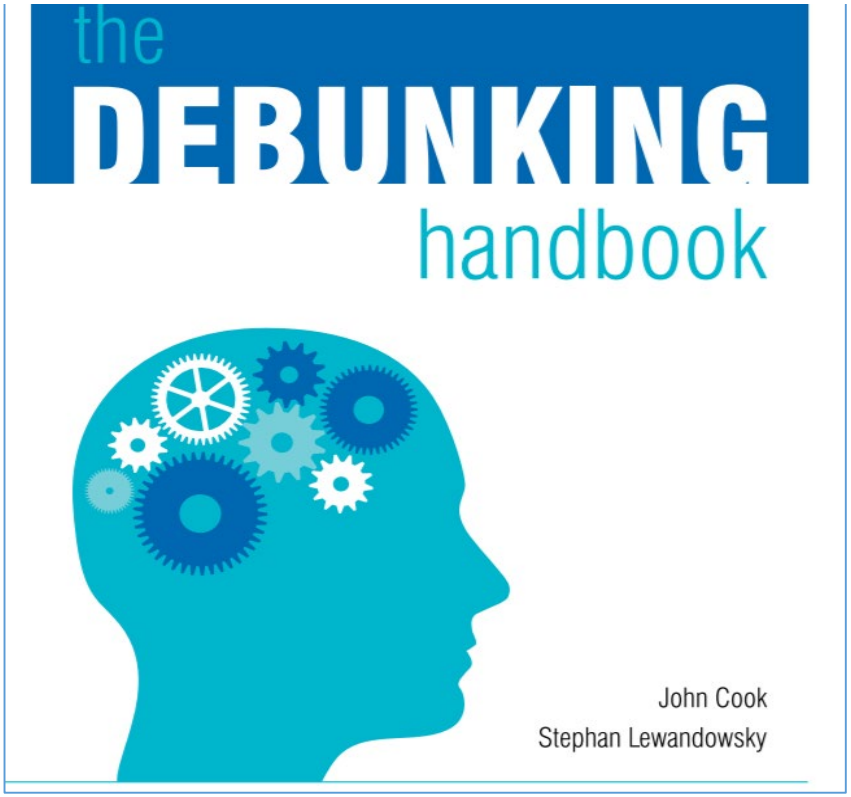
…and in some situations, prior knowledge may act as a barrier to learning



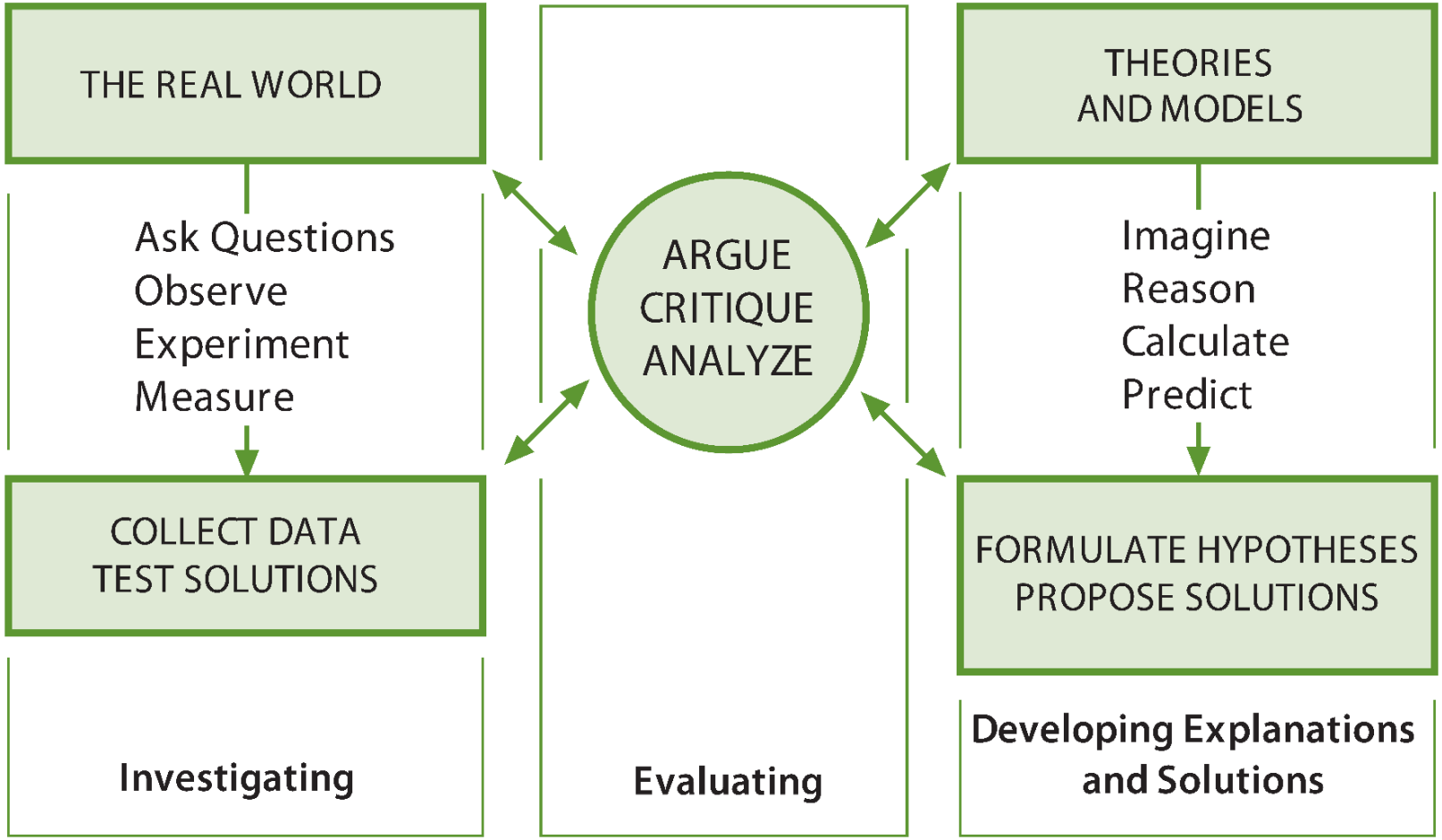
Main effect: $F(1,80) = 16$, $p < .01$, $\eta^2 = .17$; interaction: $F(1,80) = 3.2$, $p = .08$; Lombardi & Sinatra (2012)

However, the “Information Deficit” model of misunderstanding is essentially incorrect

“Educators need to understand how people process information, how they modify their existing knowledge and how worldviews affect their ability to think rationally”



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

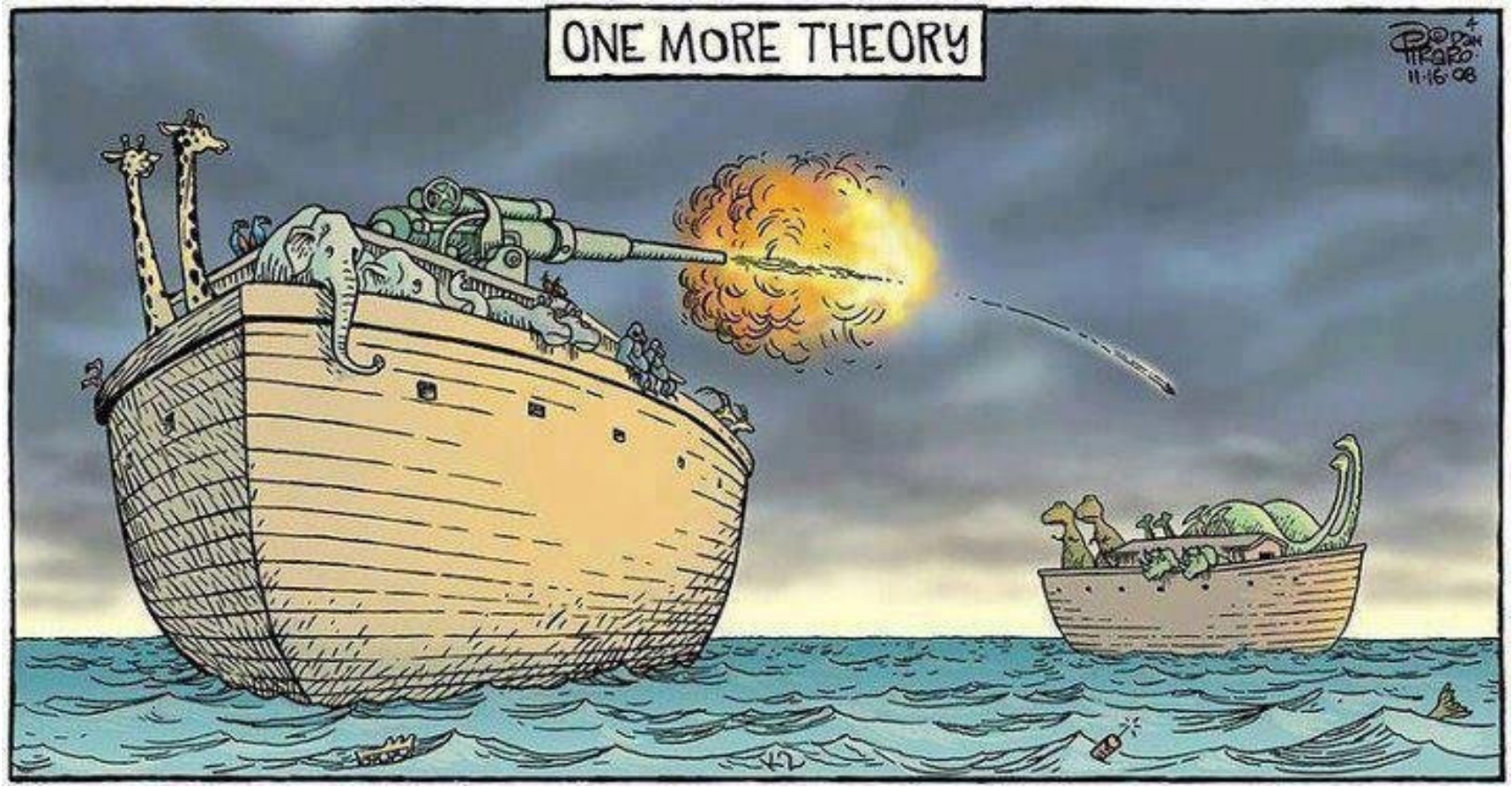


Evaluation as argument, critique, and analysis is central to scientific thinking and knowledge construction (NRC, 2012)

Relatedly, students may find scientific explanations to be implausible

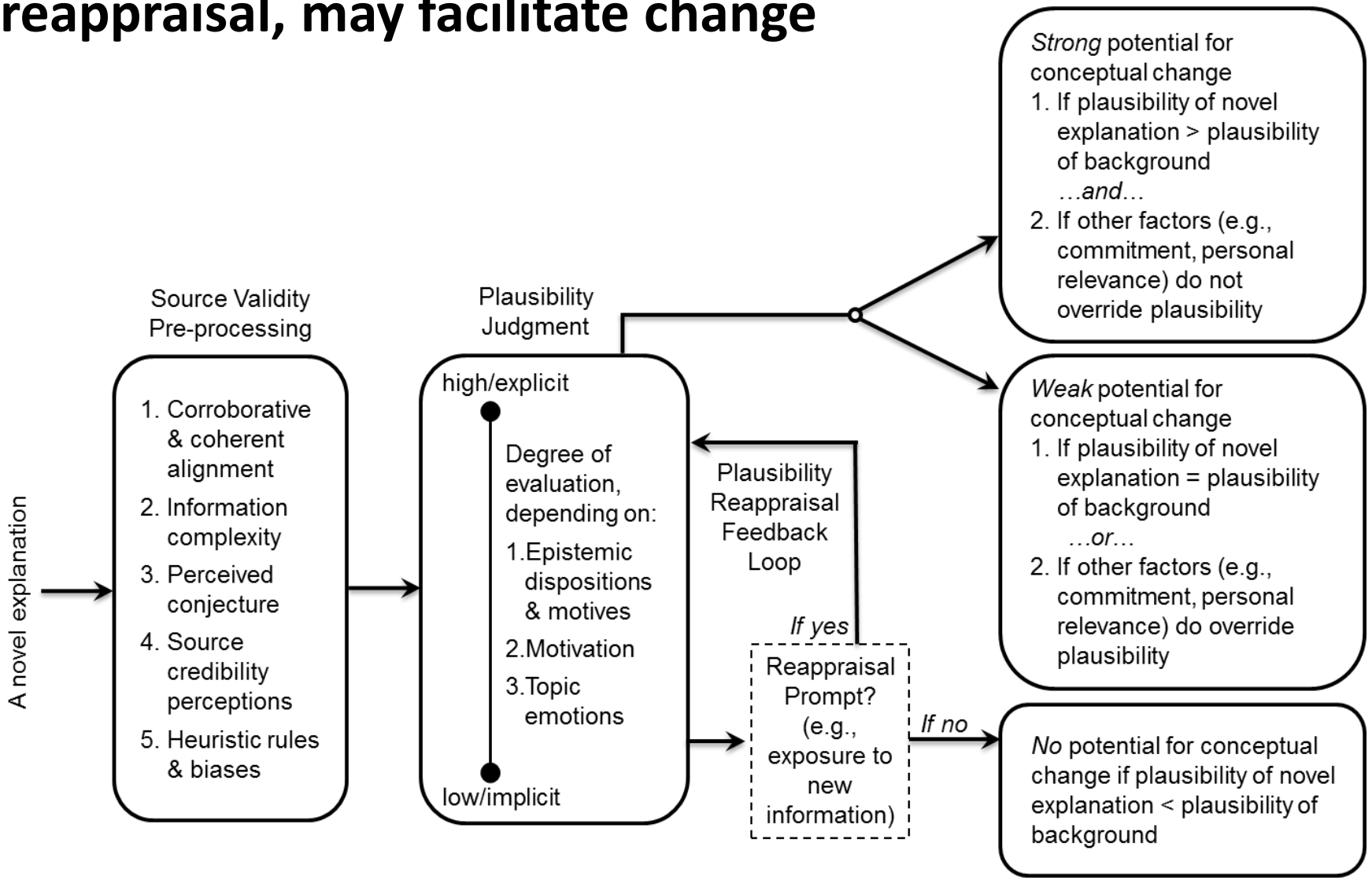
Epistemic judgments (e.g., plausibility) are often formed through automatic cognitive evaluations with little purposeful thinking (Lombardi et al., 2016a)

Plausibility is specifically an epistemic judgment associated with explanations



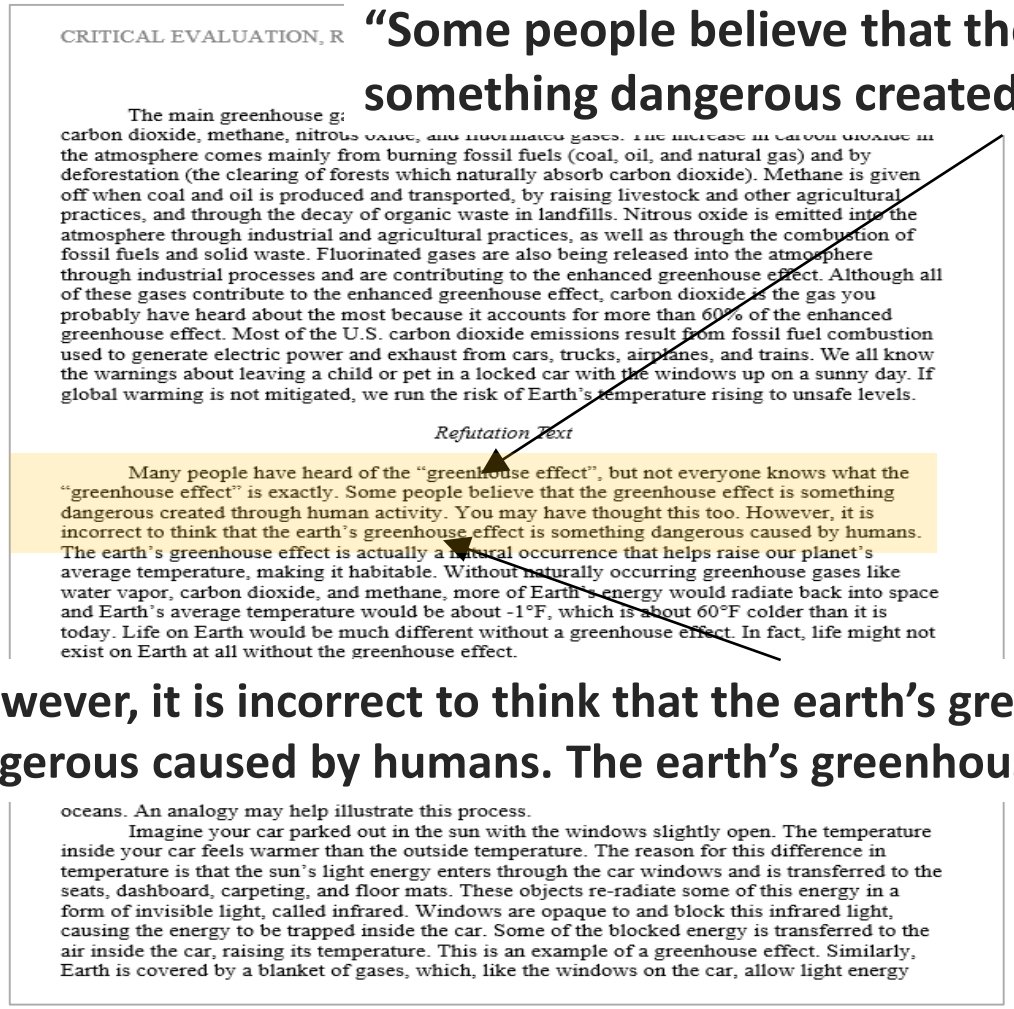
Other types of epistemic judgments are associated with evidence (e.g., credibility, trustworthiness, and reliability; Lombardi et al., 2016a)

Plausibility is a tentative epistemic judgment, and with reappraisal, may facilitate change



Model of plausibility judgments in conceptual change (PJCC; Lombardi et al., 2016a)

Refutation texts are experimental tools to investigate cognitive co-activation of prior and scientific knowledge



CRITICAL EVALUATION, R

The main greenhouse g

carbon dioxide, methane, nitrous oxide, and fluorinated gases. The increase in carbon dioxide in the atmosphere comes mainly from burning fossil fuels (coal, oil, and natural gas) and by deforestation (the clearing of forests which naturally absorb carbon dioxide). Methane is given off when coal and oil is produced and transported, by raising livestock and other agricultural practices, and through the decay of organic waste in landfills. Nitrous oxide is emitted into the atmosphere through industrial and agricultural practices, as well as through the combustion of fossil fuels and solid waste. Fluorinated gases are also being released into the atmosphere through industrial processes and are contributing to the enhanced greenhouse effect. Although all of these gases contribute to the enhanced greenhouse effect, carbon dioxide is the gas you probably have heard about the most because it accounts for more than 60% of the enhanced greenhouse effect. Most of the U.S. carbon dioxide emissions result from fossil fuel combustion used to generate electric power and exhaust from cars, trucks, airplanes, and trains. We all know the warnings about leaving a child or pet in a locked car with the windows up on a sunny day. If global warming is not mitigated, we run the risk of Earth's temperature rising to unsafe levels.

Refutation Text

Many people have heard of the "greenhouse effect", but not everyone knows what the "greenhouse effect" is exactly. Some people believe that the greenhouse effect is something dangerous created through human activity. You may have thought this too. However, it is incorrect to think that the earth's greenhouse effect is something dangerous caused by humans. The earth's greenhouse effect is actually a natural occurrence that helps raise our planet's average temperature, making it habitable. Without naturally occurring greenhouse gases like water vapor, carbon dioxide, and methane, more of Earth's energy would radiate back into space and Earth's average temperature would be about -1°F, which is about 60°F colder than it is today. Life on Earth would be much different without a greenhouse effect. In fact, life might not exist on Earth at all without the greenhouse effect.

oceans. An analogy may help illustrate this process.

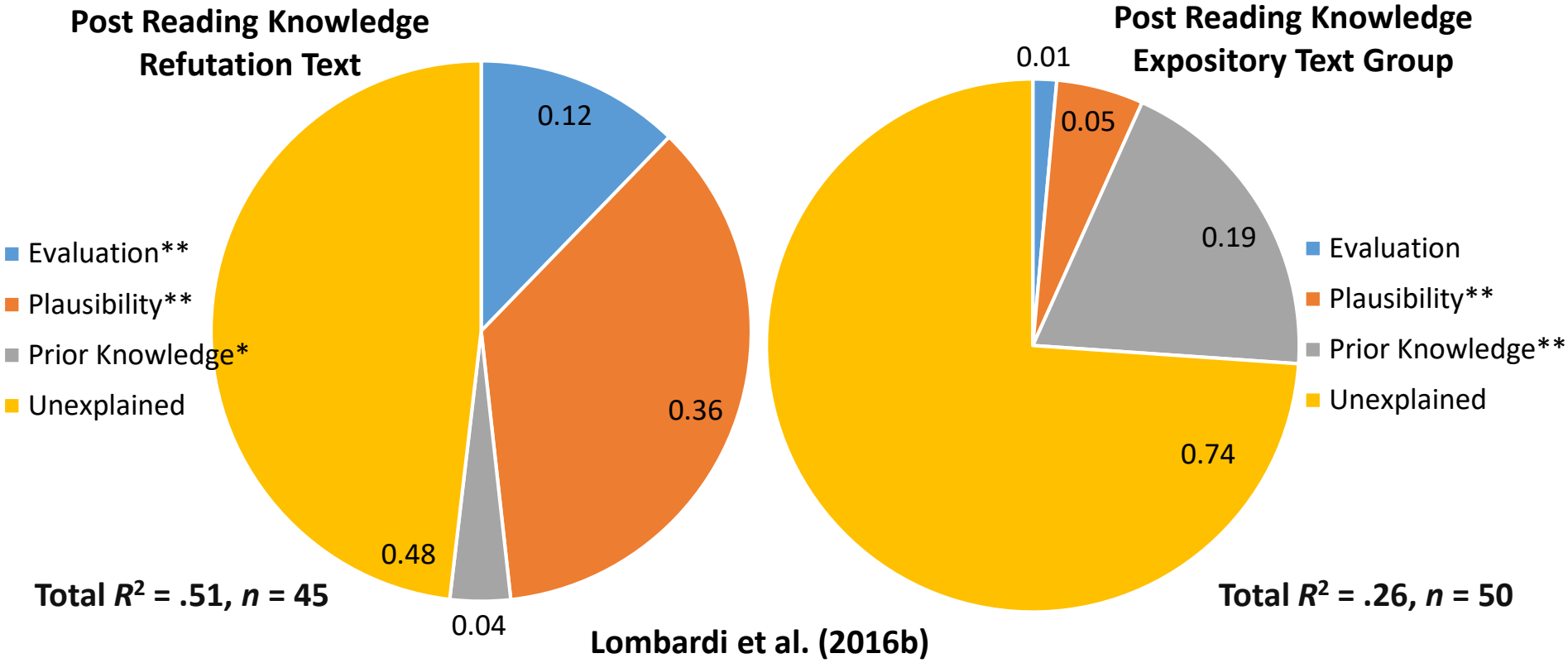
Imagine your car parked out in the sun with the windows slightly open. The temperature inside your car feels warmer than the outside temperature. The reason for this difference in temperature is that the sun's light energy enters through the car windows and is transferred to the seats, dashboard, carpeting, and floor mats. These objects re-radiate some of this energy in a form of invisible light, called infrared. Windows are opaque to and block this infrared light, causing the energy to be trapped inside the car. Some of the blocked energy is transferred to the air inside the car, raising its temperature. This is an example of a greenhouse effect. Similarly, Earth is covered by a blanket of gases, which, like the windows on the car, allow light energy

"Some people believe that the greenhouse effect is something dangerous created through human activity."

"However, it is incorrect to think that the earth's greenhouse effect is something dangerous caused by humans. The earth's greenhouse effect is actually…"

Lombardi et al. (2016b)

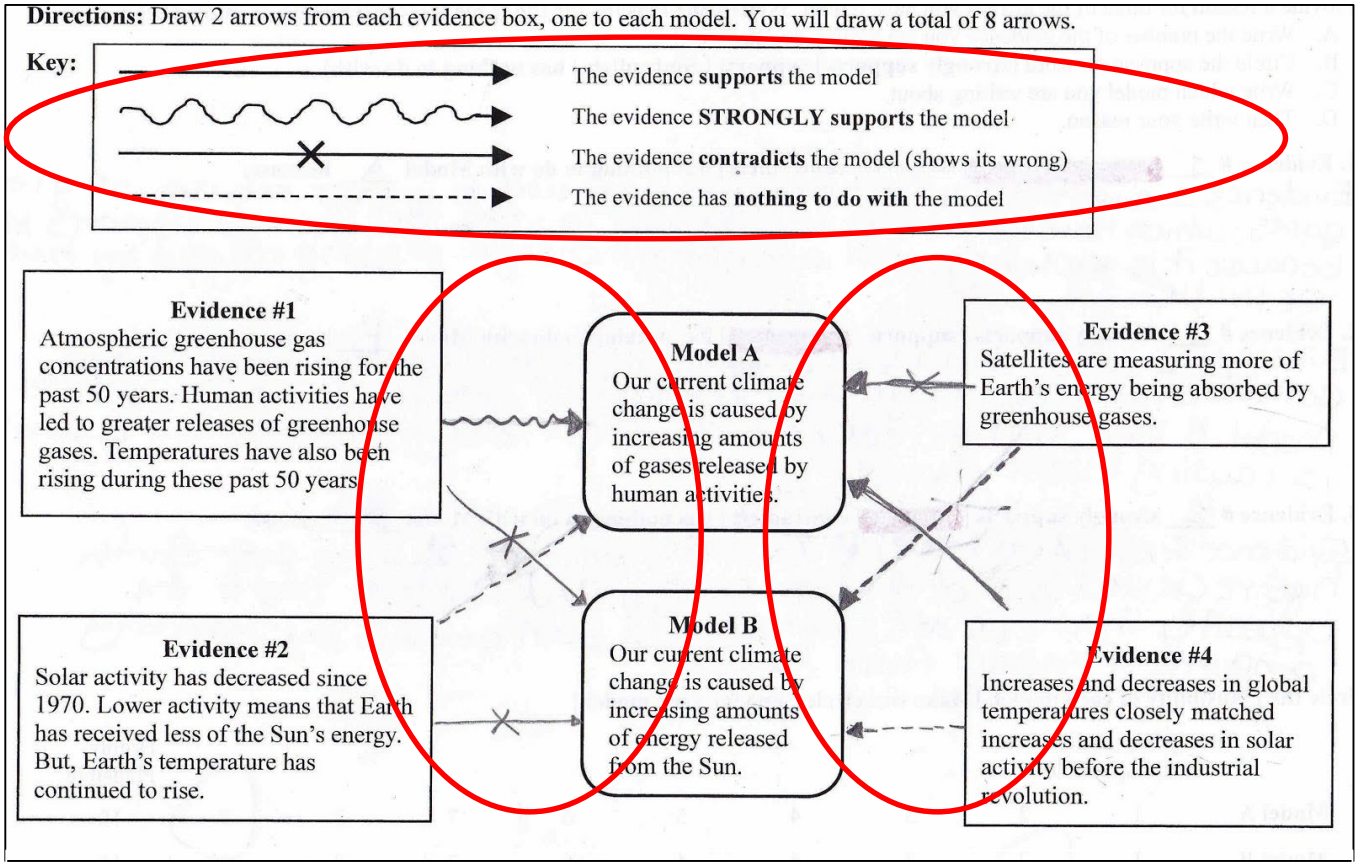
Student who were more evaluative and reappraised plausibility shifted toward more scientific knowledge...



…but only after reading a refutation text…and refutation texts are difficult to design and use effectively in authentic classroom instruction

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

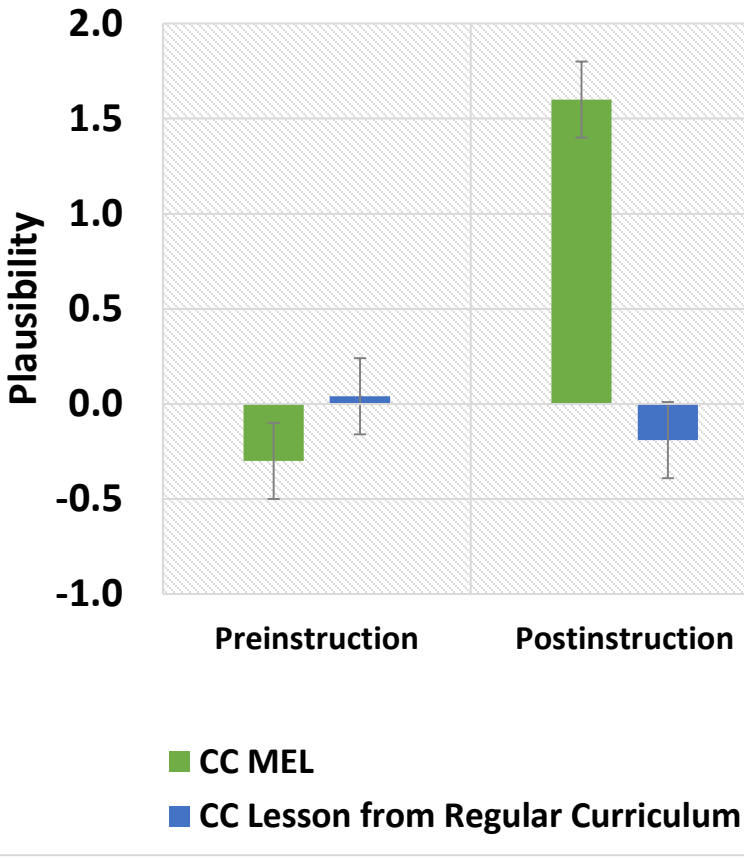
Chinn & colleagues (2012, 2014)



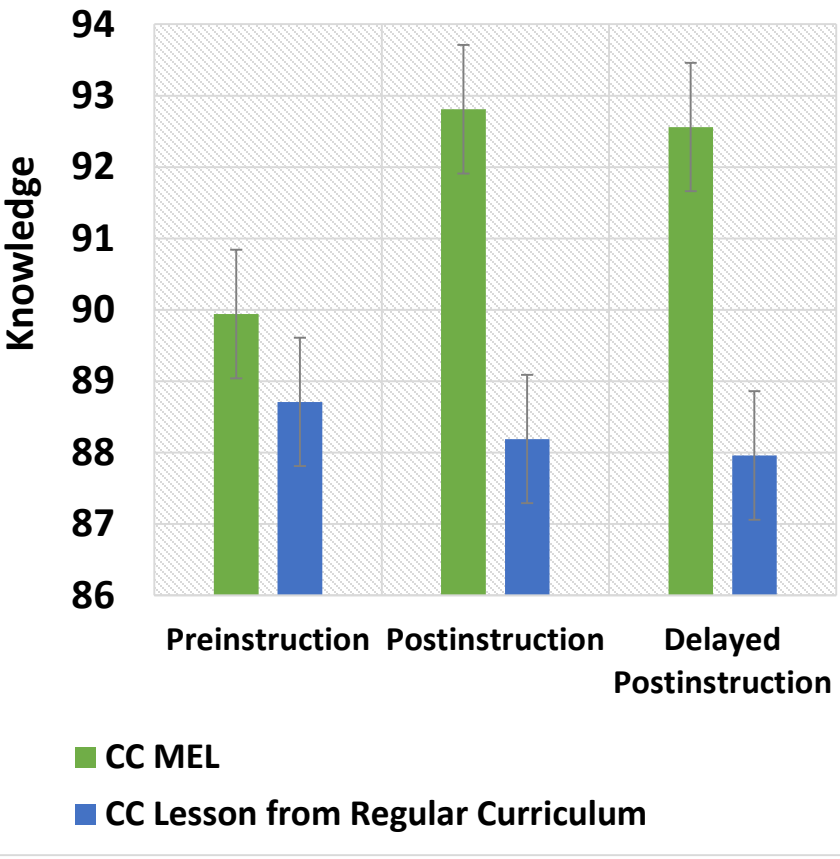
Example of student completed Model-Evidence Link (MEL) diagram

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

The climate change MEL resulted in shifts in middle school students' plausibility and increased knowledge



$F(1,167) = 10.89$, $p = .001$, $\eta^2 = .061$

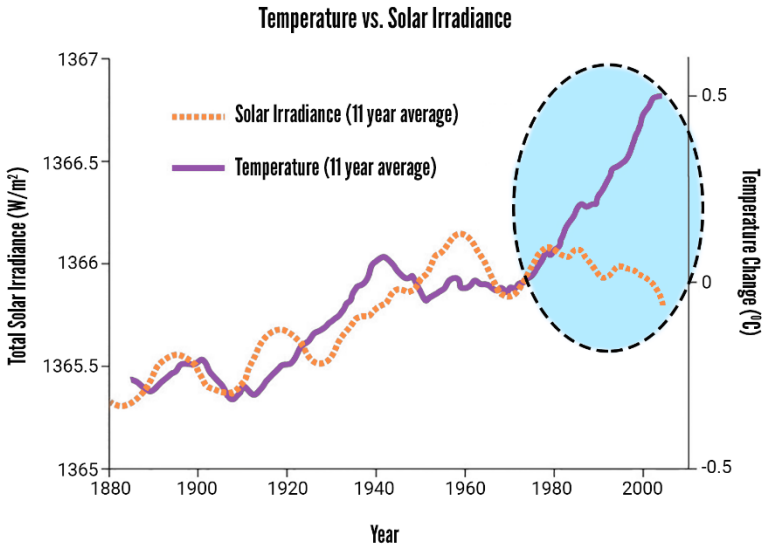


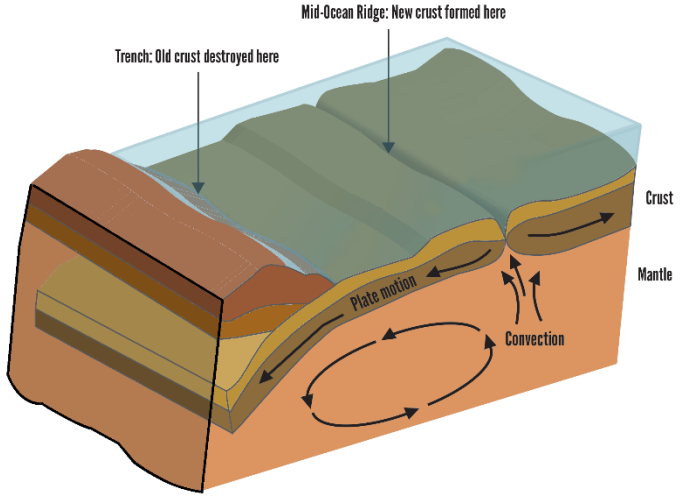
$F(2,93) = 3.24$, $p = .044$, $\eta^2 = .065$

Lombardi et al. (2013)

We expanded and replicated this study with secondary students who experienced four different MELs

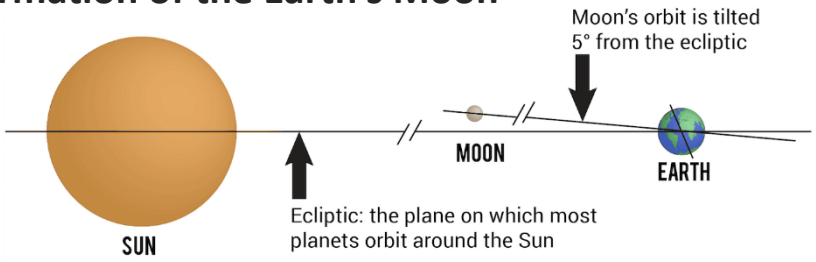
Causes of current climate change

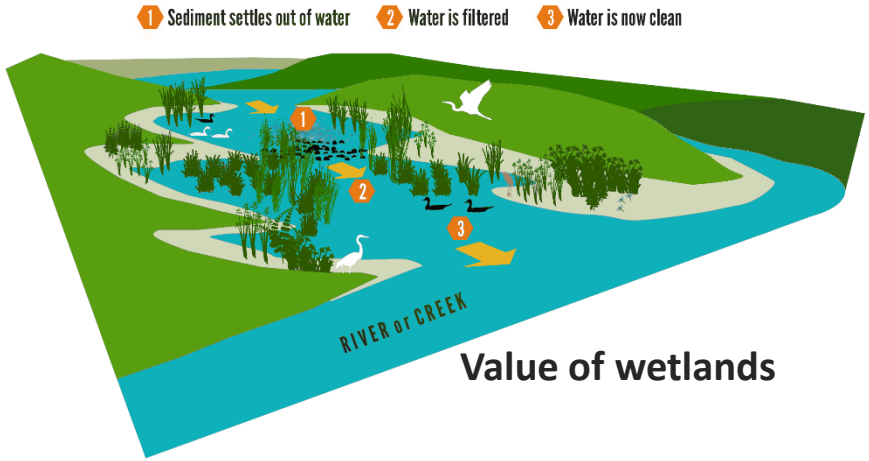




Hydraulic fracturing & earthquakes

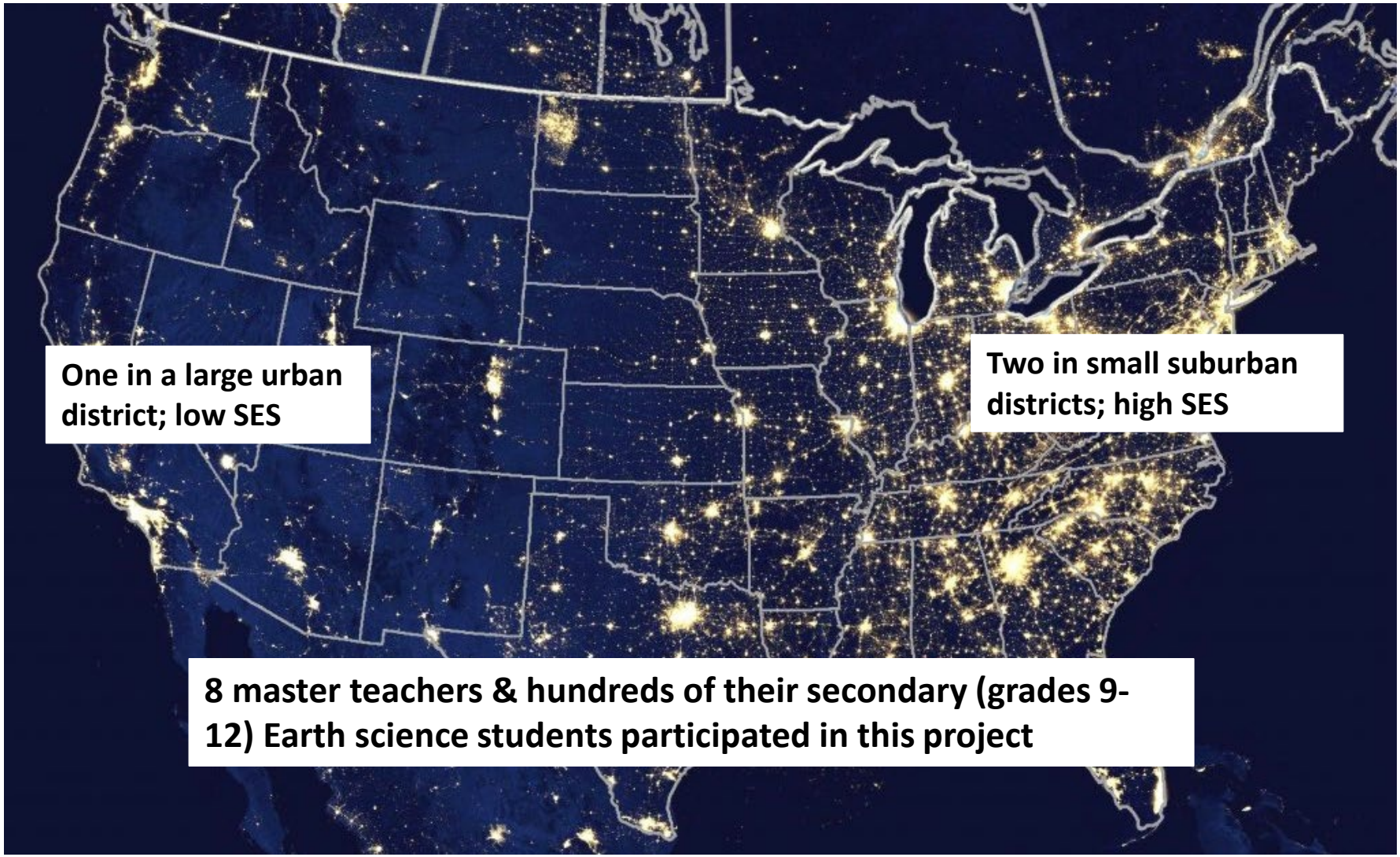
Formation of the Earth's Moon



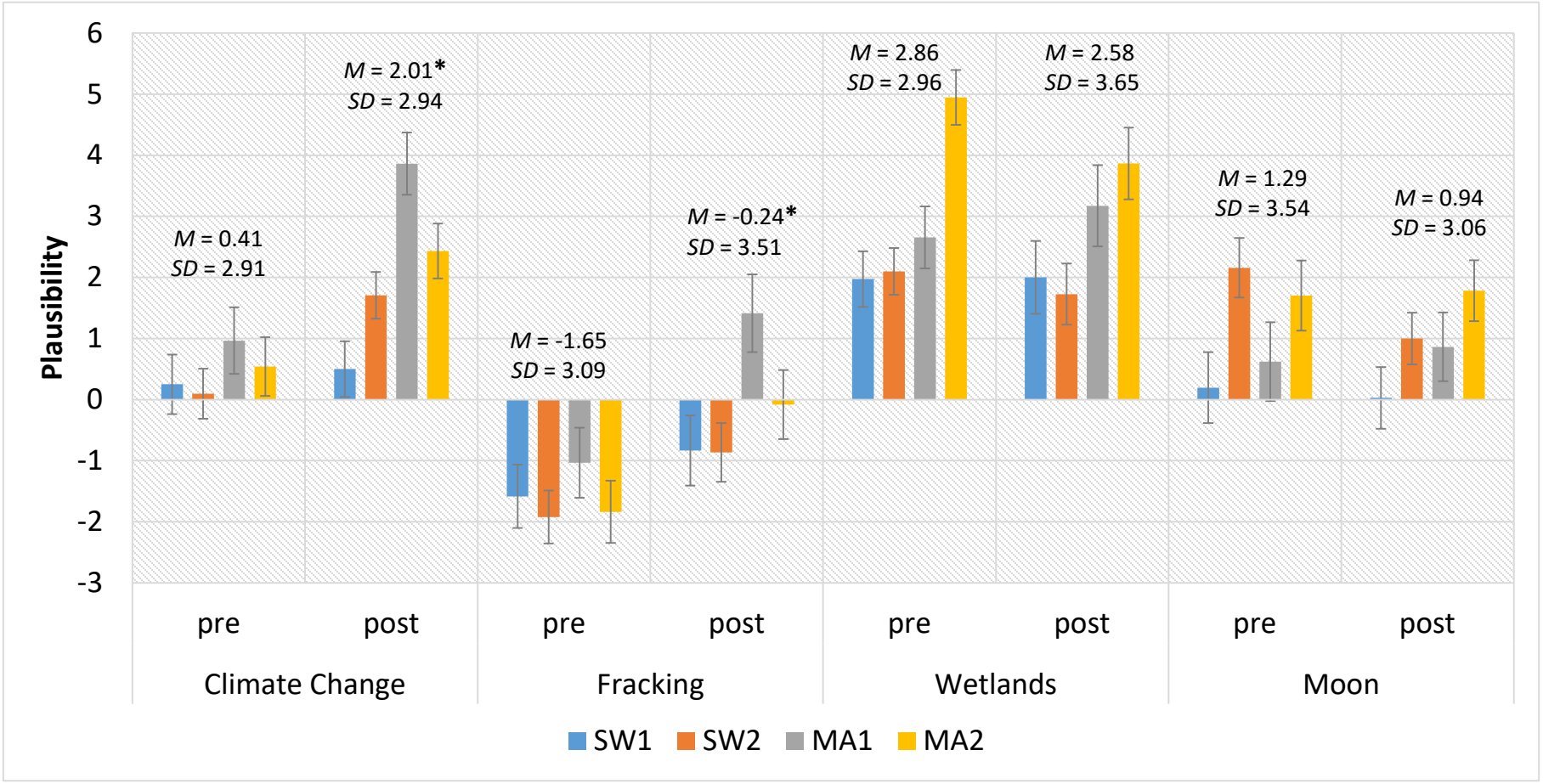


Value of wetlands

This project involved three school districts from very different parts of the US



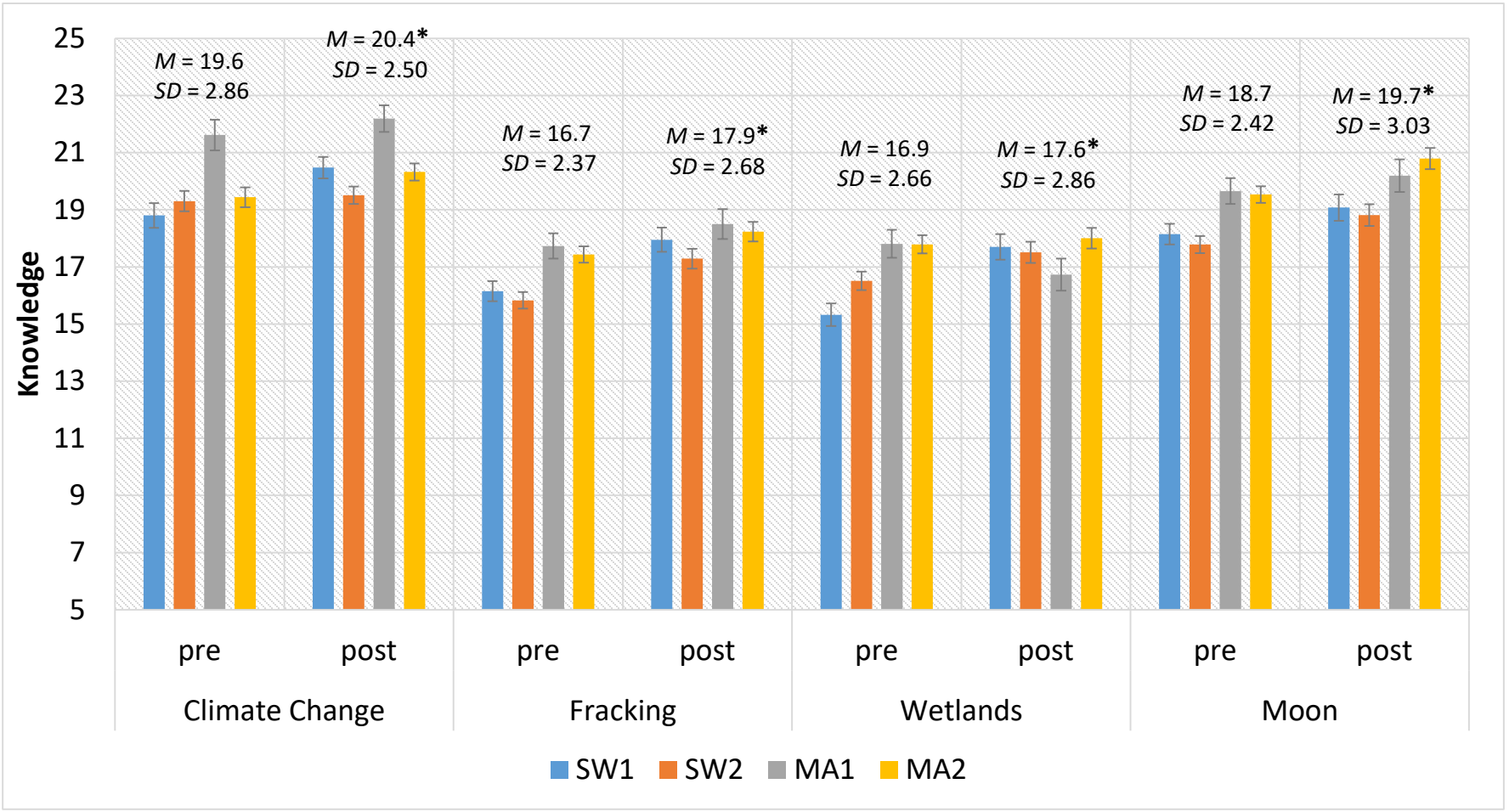
Year 2 pilot study results revealed plausibility shifts for some topics (e.g., climate change), but not for others



$F(12,546) = 12.1$, $p < .001$, $\eta_p^2 = .099$

Lombardi et al. (2018)

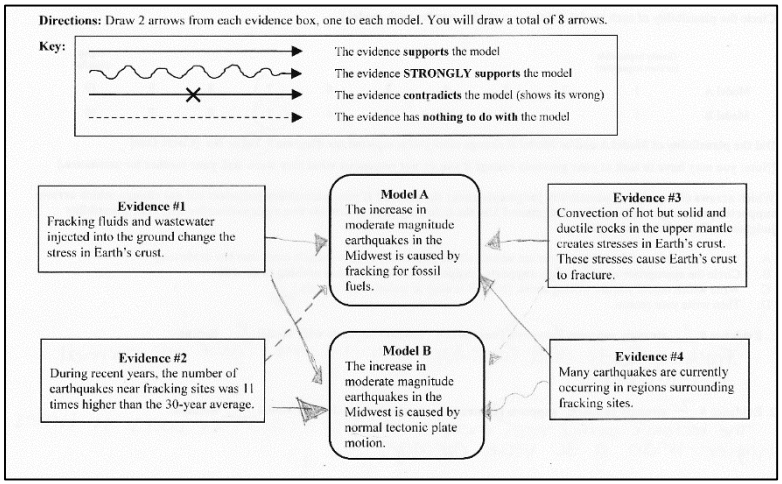
However, all topics showed increases in knowledge



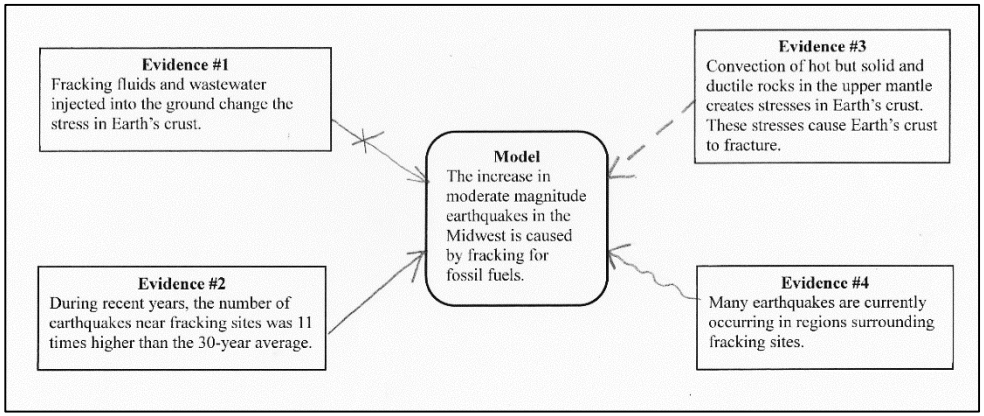
$F(12,546) = 15.1$, $p < .001$, $\eta_p^2 = .251$

Lombardi et al. (2018)

In Year 3, we conducted a quasi-experiment comparing three different tasks



The Model-Evidence Link (MEL) diagram, 4 lines of evidence, 2 alternatives



The Mono-MEL diagram, 4 lines of evidence, only 1 alternative

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

Directions: Use the following codes to indicate how well each evidence supports each model. You should put a code into each blank table cell.

Key:

S = The evidence **supports** the model
SS = The evidence **STRONGLY supports** the model
C = The evidence **contradicts** the model (shows its wrong)
N = The evidence has **nothing to do with** the model

	Model A The increase in moderate magnitude earthquakes in the Midwest is caused by fracking for fossil fuels.	**Model B** The increase in moderate magnitude earthquakes in the Midwest is caused by normal tectonic plate motion.
Evidence #1 Fracking fluids and wastewater injected into the ground change the stress in Earth's crust.	C	N
Evidence #2 During recent years, the number of earthquakes near fracking sites was 11 times higher than the 30-year average.	S	N
Evidence #3 Convection of hot but solid and ductile rocks in the upper mantle creates stresses in Earth's crust. These stresses cause Earth's crust to fracture.	N	SS
Evidence #4 Many earthquakes are currently occurring in regions surrounding fracking sites.	S	C

The Model-Evidence Link Table (MET), 4 lines of evidence, 2 alternatives

In this scaffold, students complete a written explanation task after drawing their diagram

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

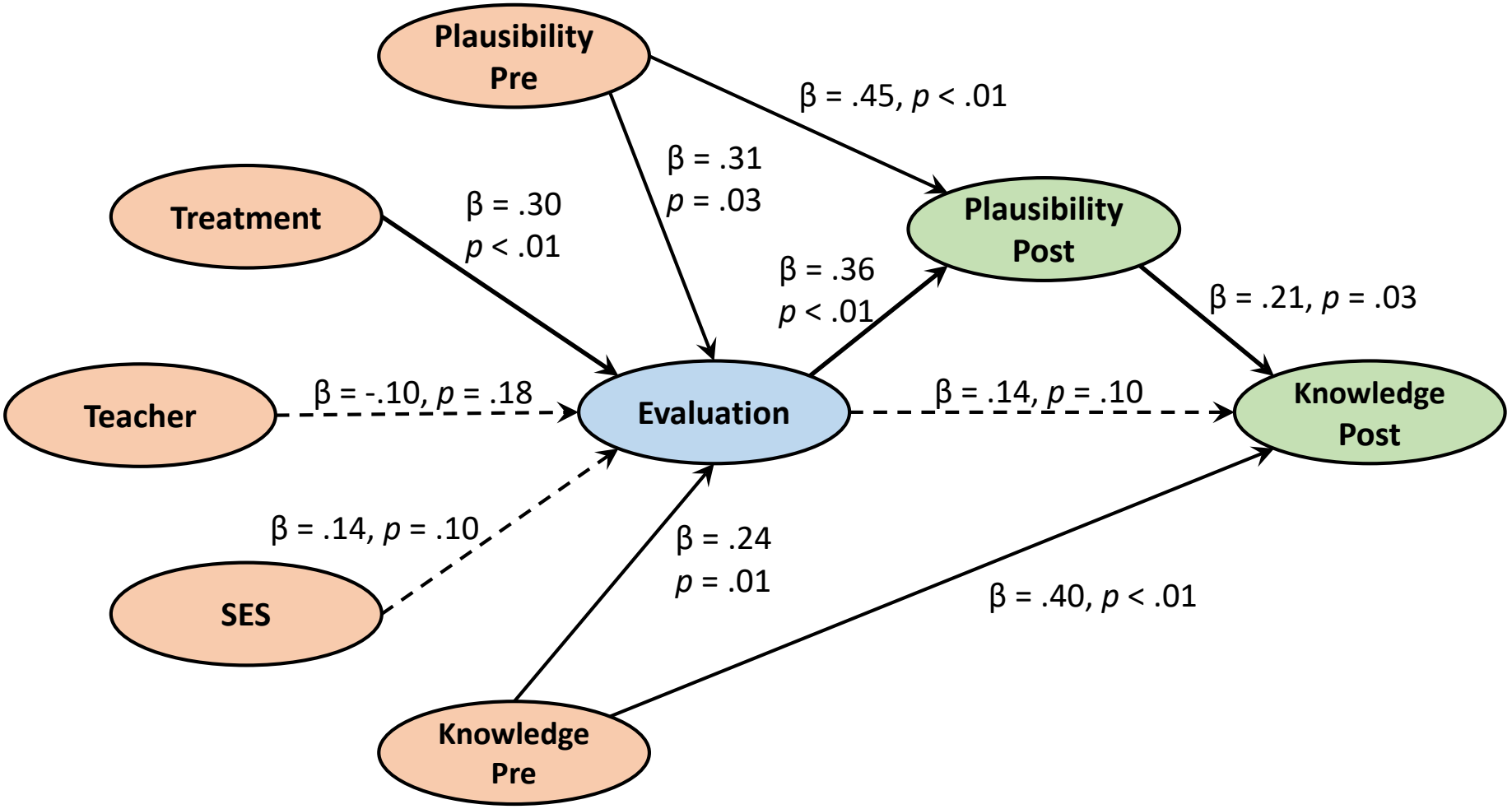
A. Write the number of the evidence you are writing about.
B. Circle the appropriate word (**strongly supports | supports | contradicts | has nothing to do with**).
C. Write which model you are writing about.
D. Then write your reason.

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.

Deeper evaluations facilitated participants' plausibility reappraisals and greater knowledge



GoF = .437 (large explanatory power); APC = .265, *p* < .001; ARS = .330, *p* < .001; AVIF = 1.12; AFVIF = 1.46; and NLBCDR = 1.0; Lombardi et al. (2018a)

Researchers & instructors need to help students scientifically evaluate & reappraise their epistemic judgments…

…and such scientific thinking practices are essential for development by all so that we can productively address both mitigation & adaption

We must teach K-16 students to source, analyze, critique & judge the plausibility of both scientific & lay explanations (e.g., from online sources) for evaluating the truthfulness of solutions to equitably address human-induced climate change

Acknowledgements and thank you!

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Please visit our current project site at https://serc.carleton.edu/mel/

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…and our research team site at http://sciencelearning.net