Think again:
Shifting epistemic judgments toward the scientific

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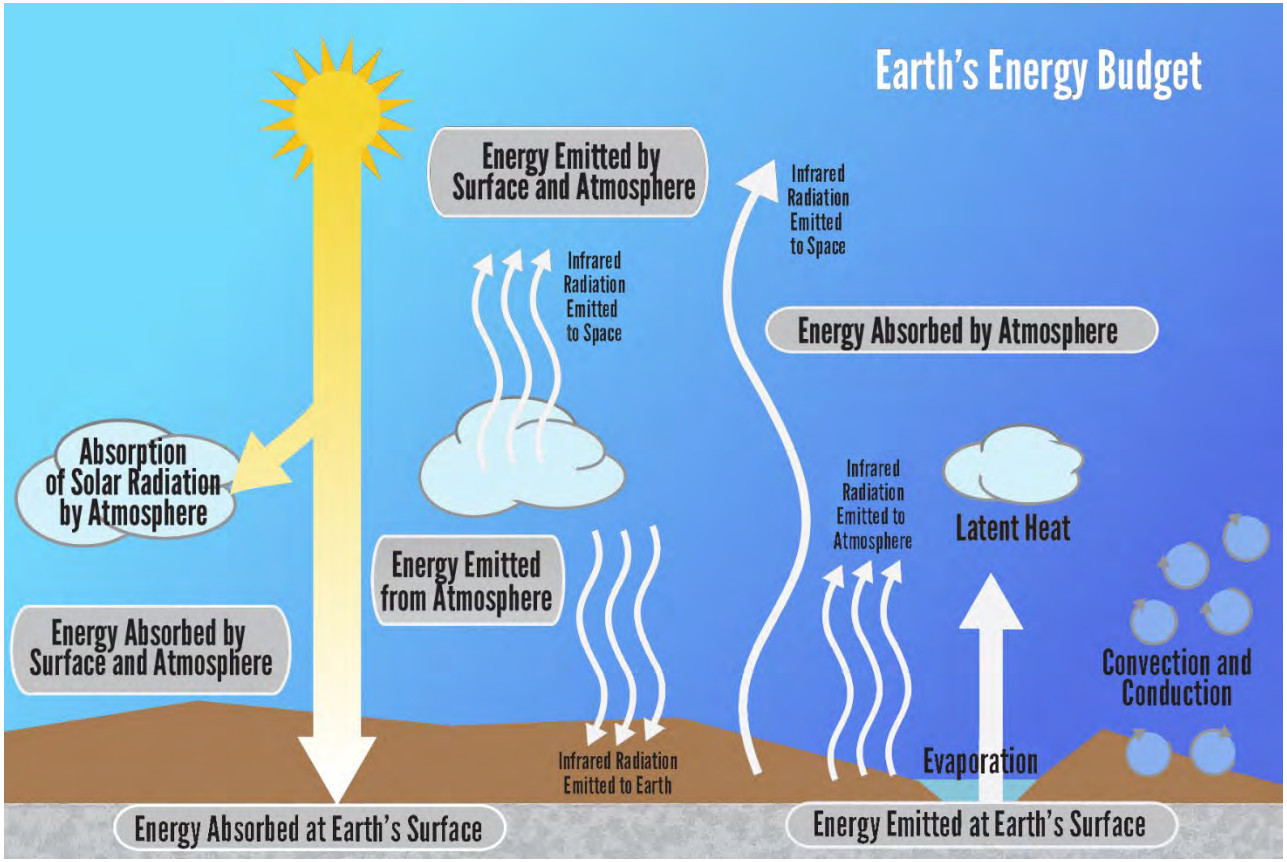

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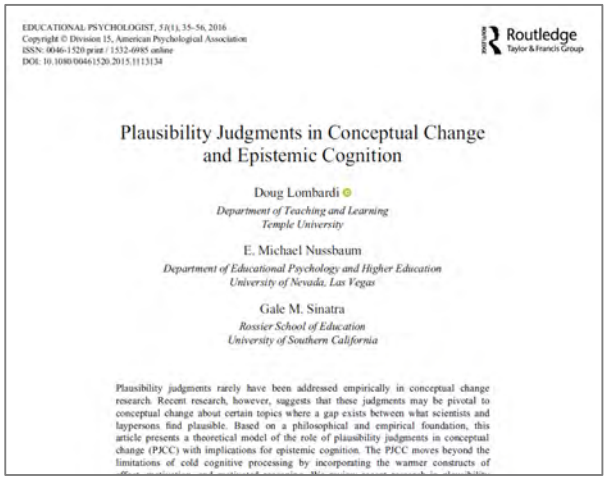
This presentation will overview my research program in three parts



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Plausibility Judgments in Conceptual Change and Epistemic Cognition

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Plausibility judgments rarely have been addressed empirically in conceptual change research. Recent research, however, suggests that these judgments may be pivotal to conceptual change about certain topics where a gap exists between what scientists and laypersons find plausible. Based on a philosophical and empirical foundation, this article presents a theoretical model of the role of plausibility judgments in conceptual change (PJCC) with implications for epistemic cognition. The PJCC moves beyond the limitations of cold cognitive processing by incorporating the warmer constructs of

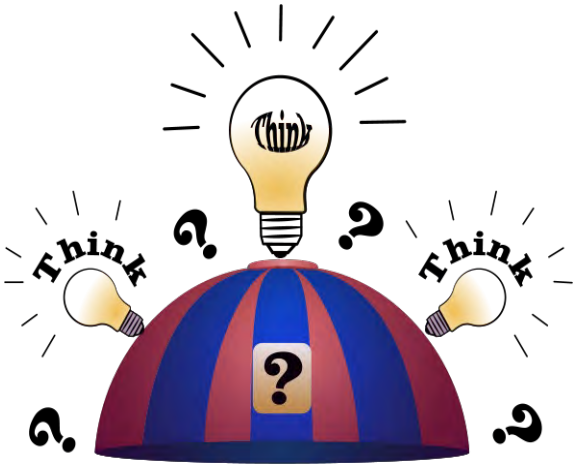
Learning and Instruction

WILEY

Contemporary Educational Psychology

Empirical study

Scaffolding scientific thinking: Students' evaluations and judgments during Earth science knowledge construction

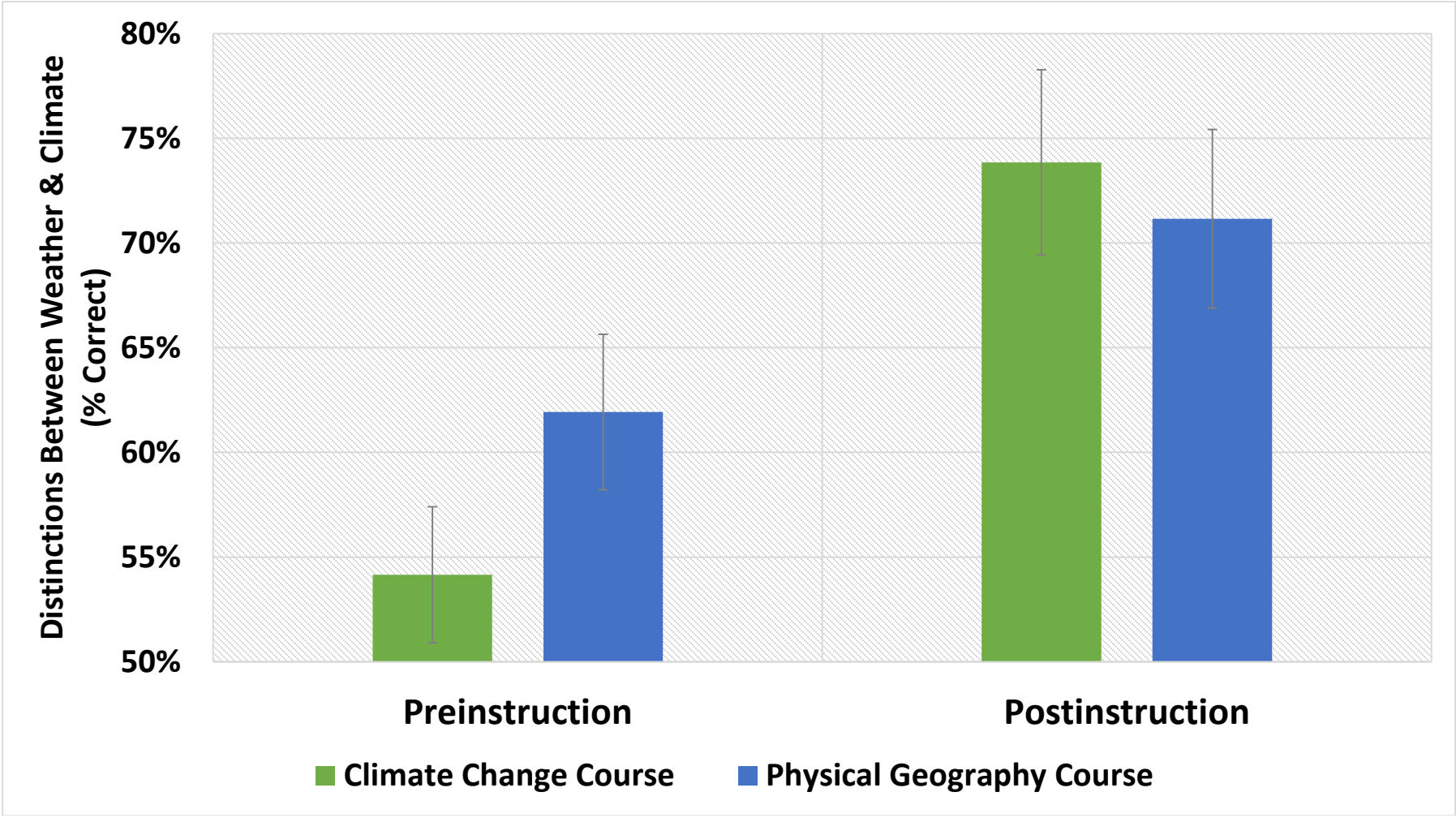


Background of theoretical and empirical foundations

Some details on recent studies

A brief look toward future directions

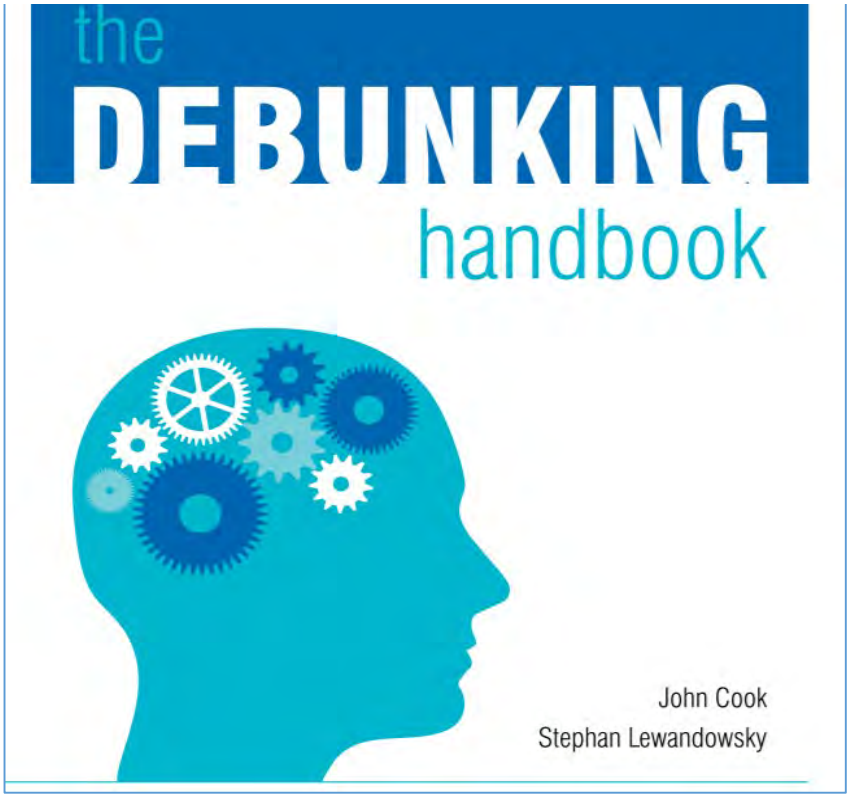
Learners' knowledge may be different than scientifically accurate conceptions



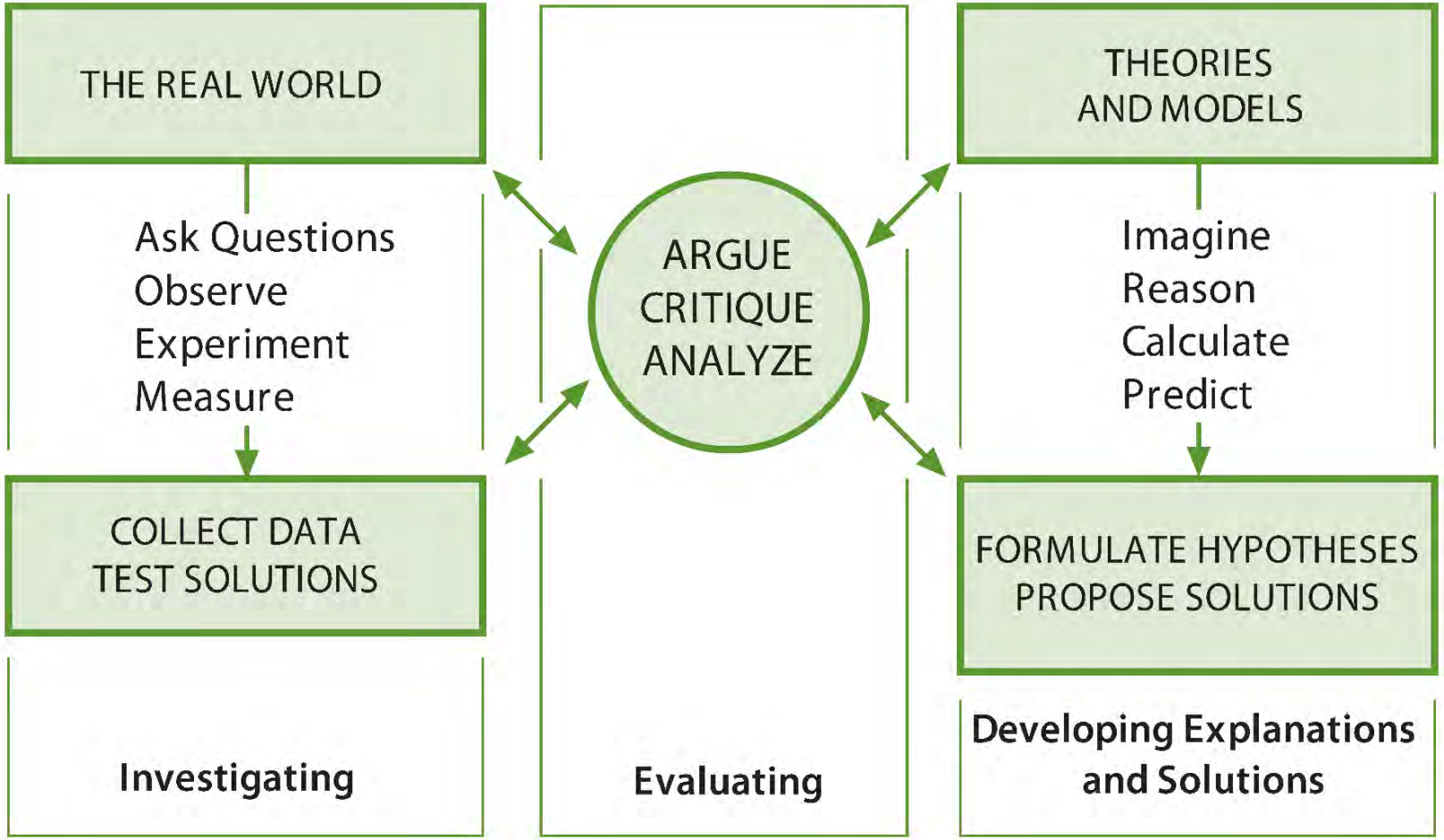
Main effect: $F(1,80) = 16$, $p < .01$, $\eta^2 = .17$; interaction: $F(1,80) = 3.2$, $p = .08$; Lombardi & Sinatra (2012)

However, when addressing misunderstandings, we should be wary of the “Information Deficit” model

“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

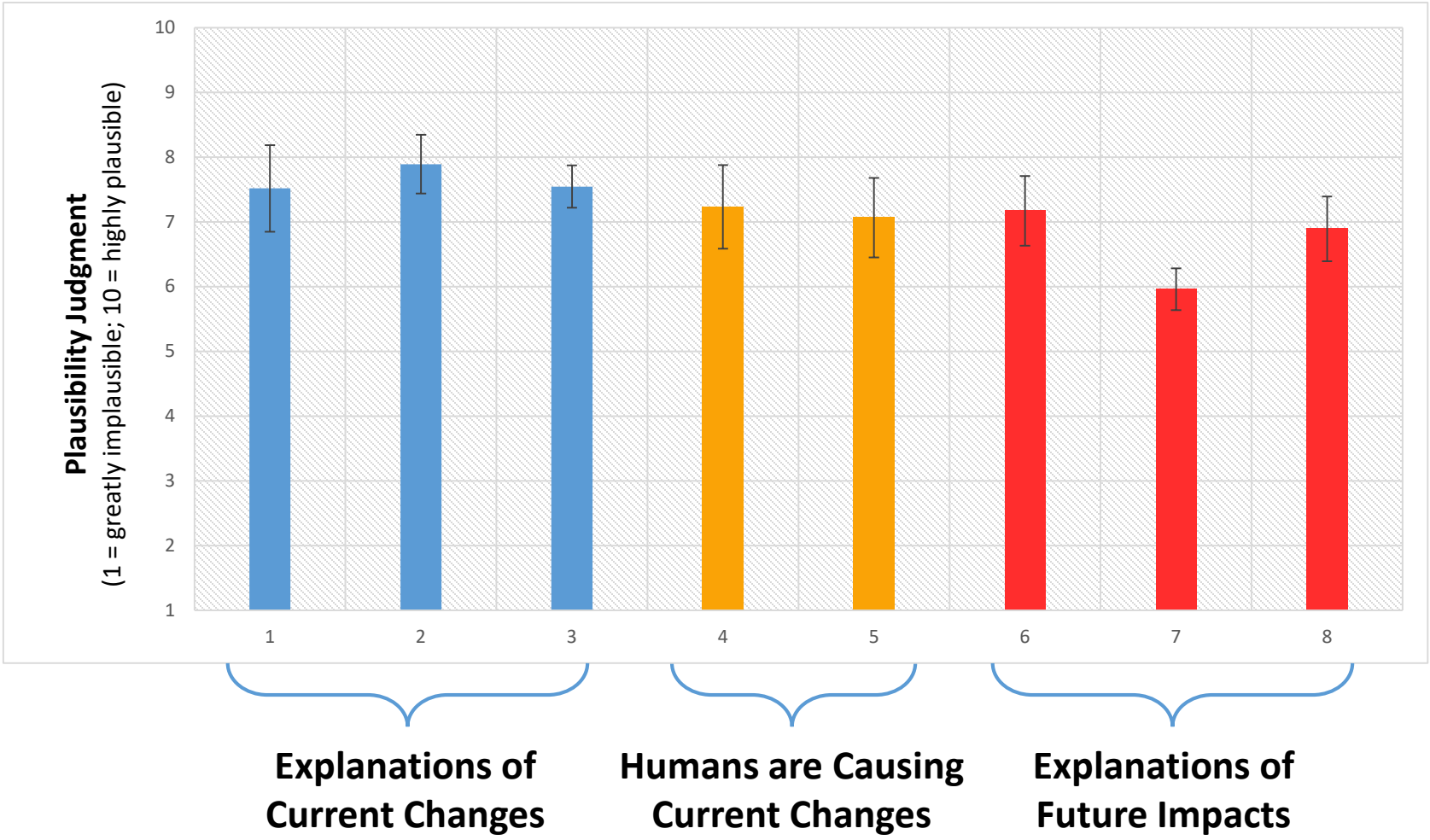


Evaluation as argument, critique, and analysis is central to scientific thinking and knowledge construction (NRC, 2012)

Relatedly, students may find scientific explanations to be implausible

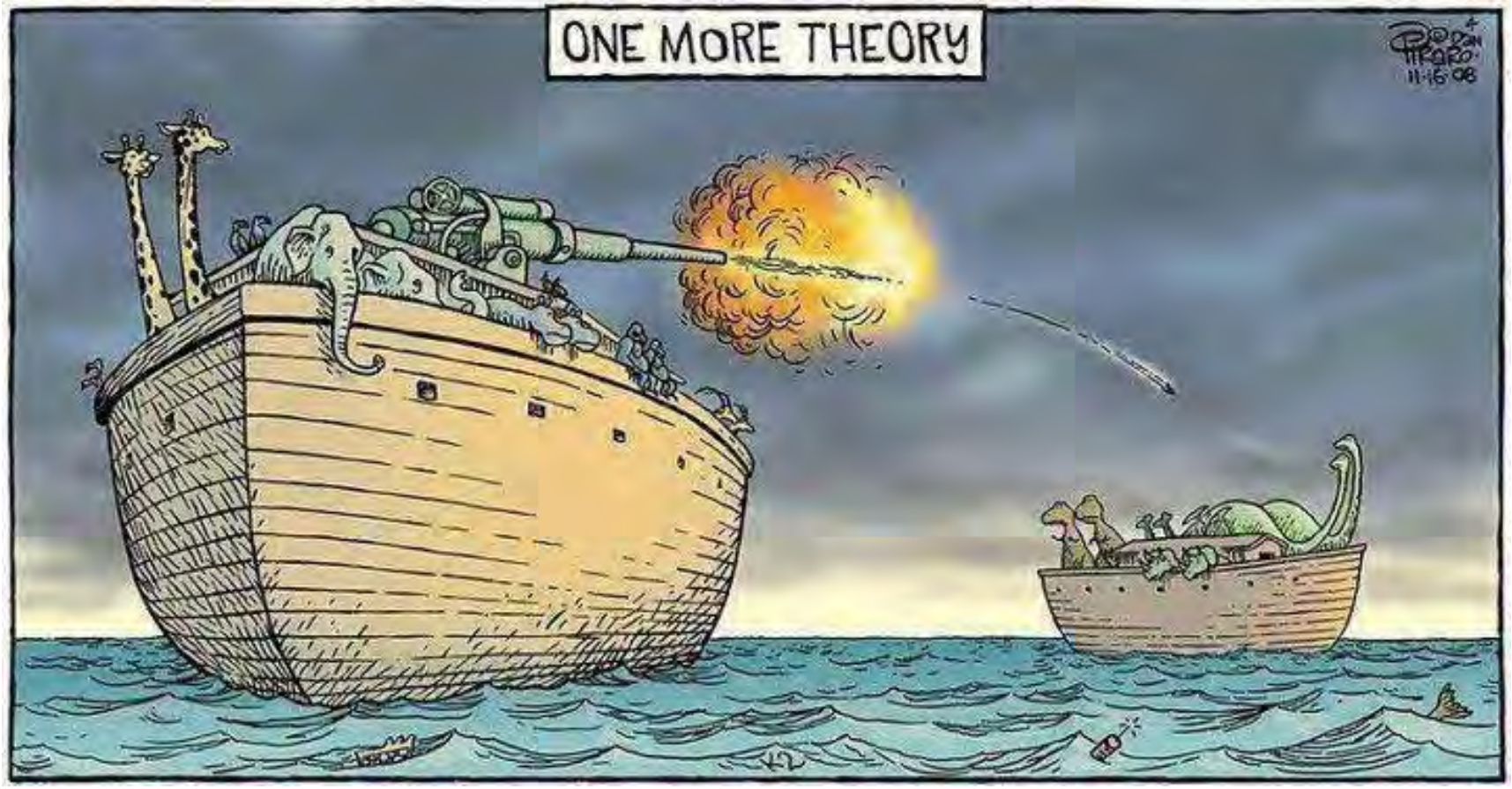
Epistemic judgments (e.g., plausibility) may be formed through automatic cognitive evaluations with little purposeful thinking (Lombardi et al., 2016a)

…e.g., plausibility about scientific statements of future climate change impacts is somewhat low



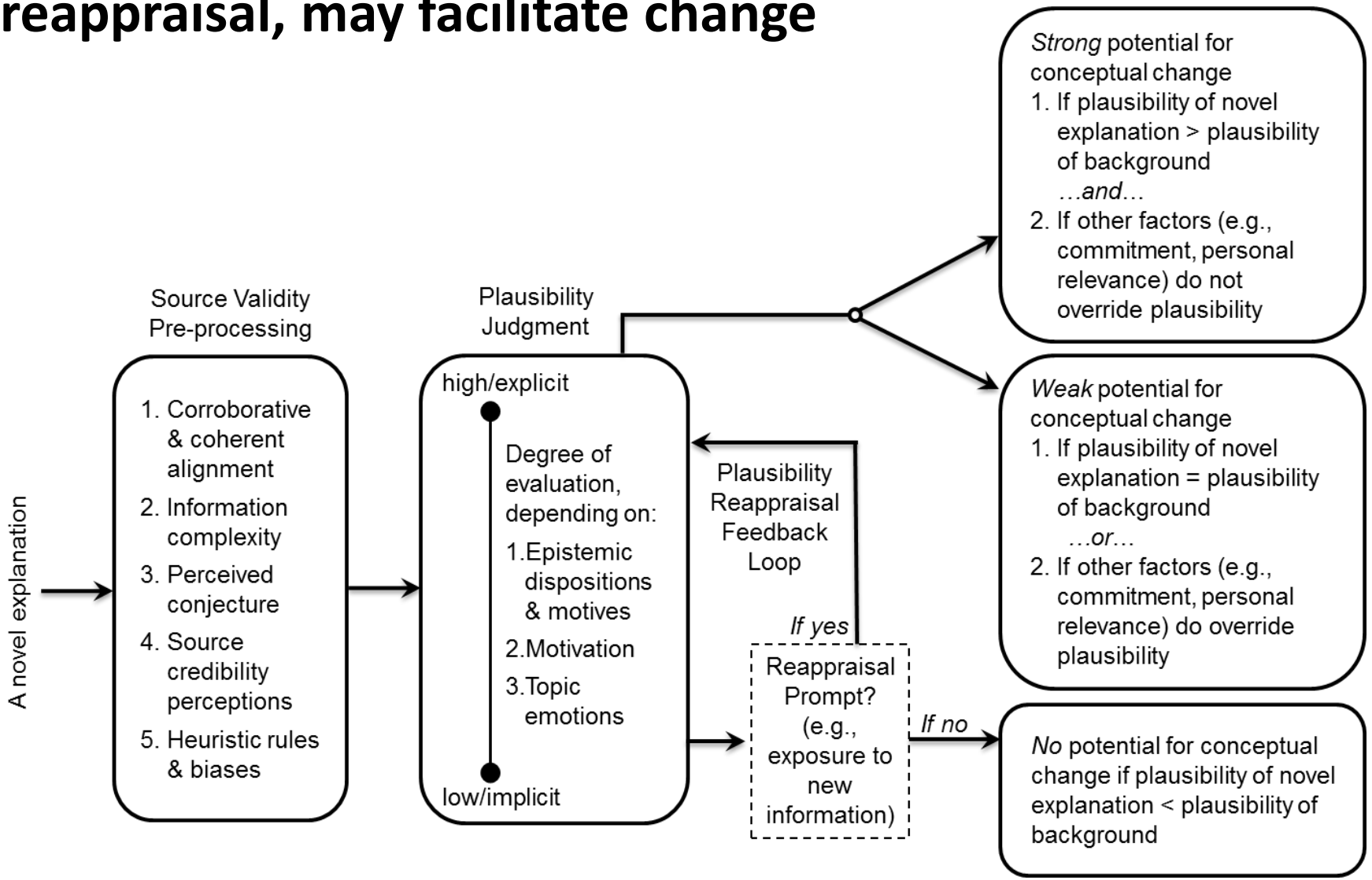
N **= 432 (unpublished analysis with data from Lombardi et al., 2012, 2013, 2016; includes adolescent and adult perceptions at various times of the year and locations across the US)**

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)

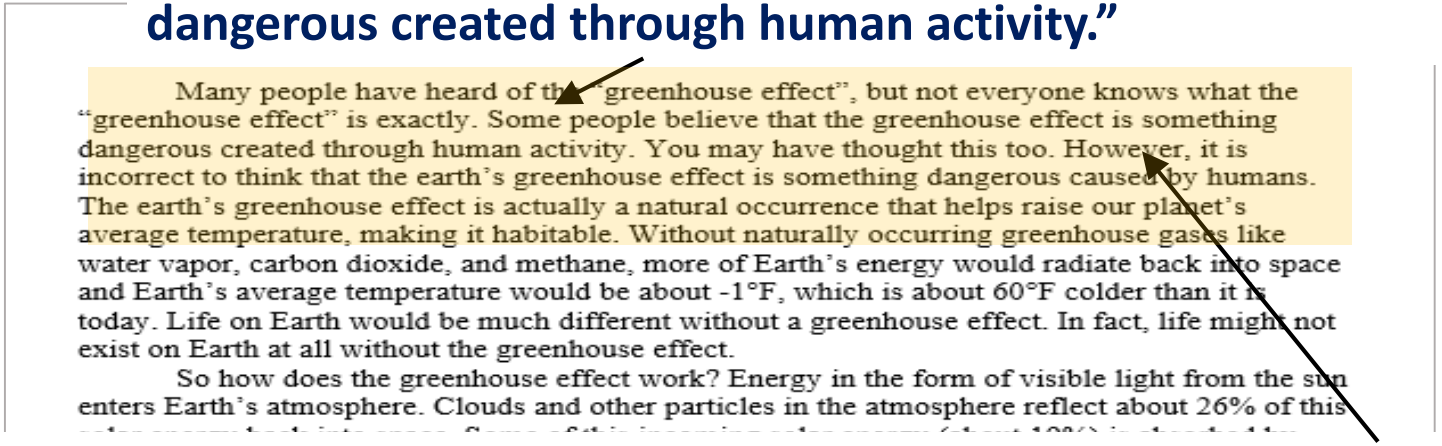
Plausibility is a tentative epistemic judgment, and with reappraisal, may facilitate change



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

Refutation texts are oft-used experimental tools for investigating co-activation of prior & expert knowledge

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



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.

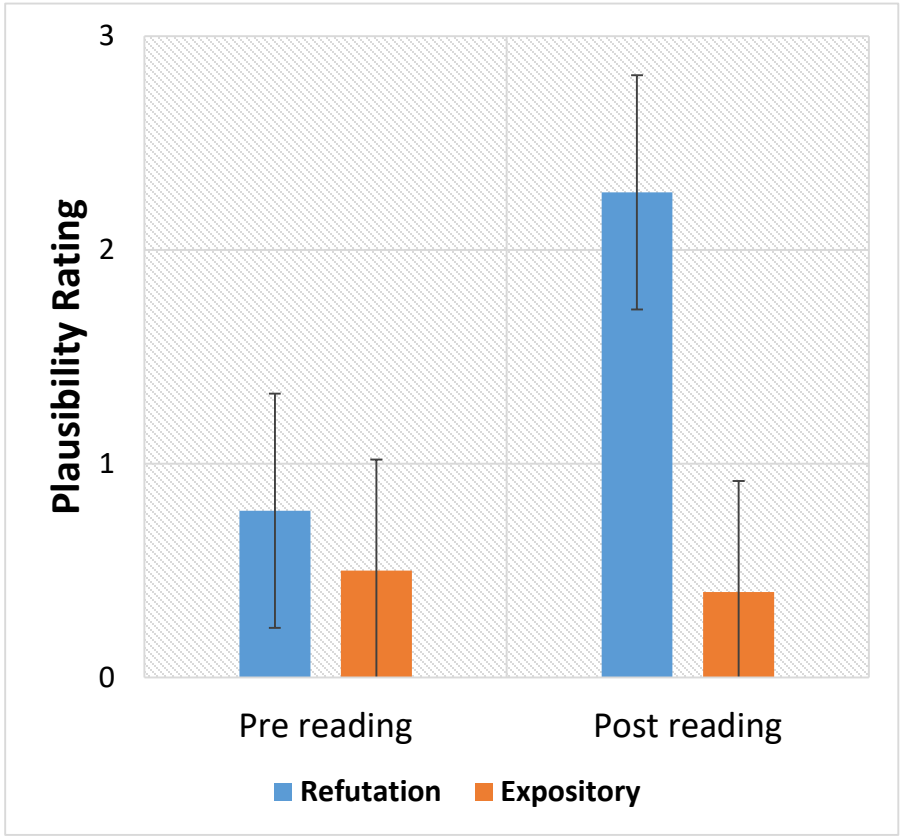
So how does the greenhouse effect work? Energy in the form of visible light from the sun enters Earth's atmosphere. Clouds and other particles in the atmosphere reflect about 26% of this

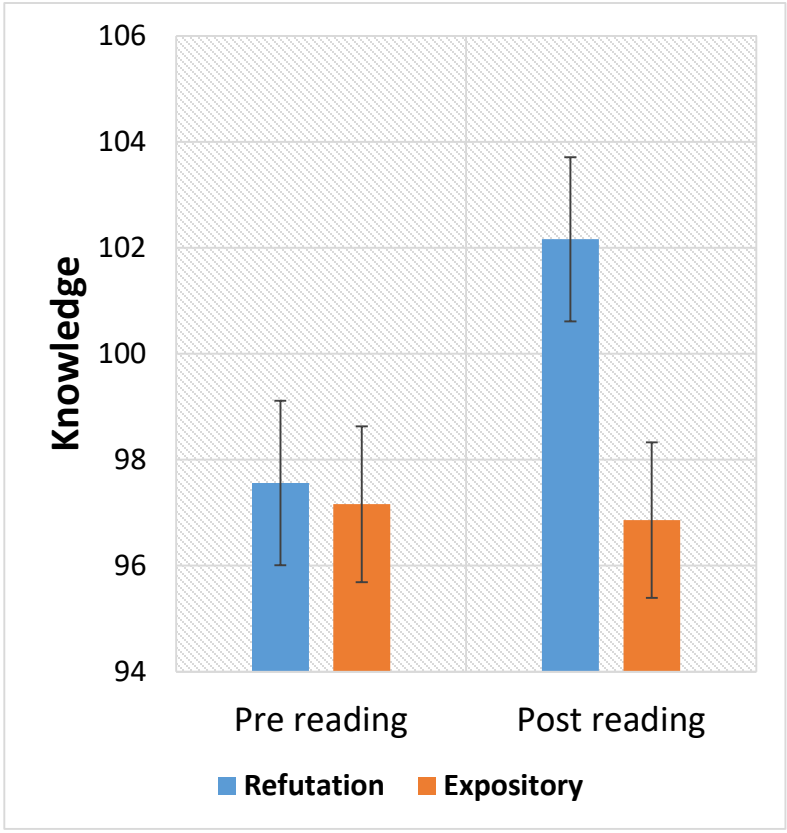
"However, it is incorrect to think that the earth's greenhouse effect is something dangerous caused by humans. The earth's greenhouse effect is actually…"

RQ1: How does a refutation text about climate change shift plausibility and change knowledge about the topic?

RQ2: How do the participants' evaluations, plausibility, and knowledge differ between refutation and expository text? (Lombardi et al., 2016b)

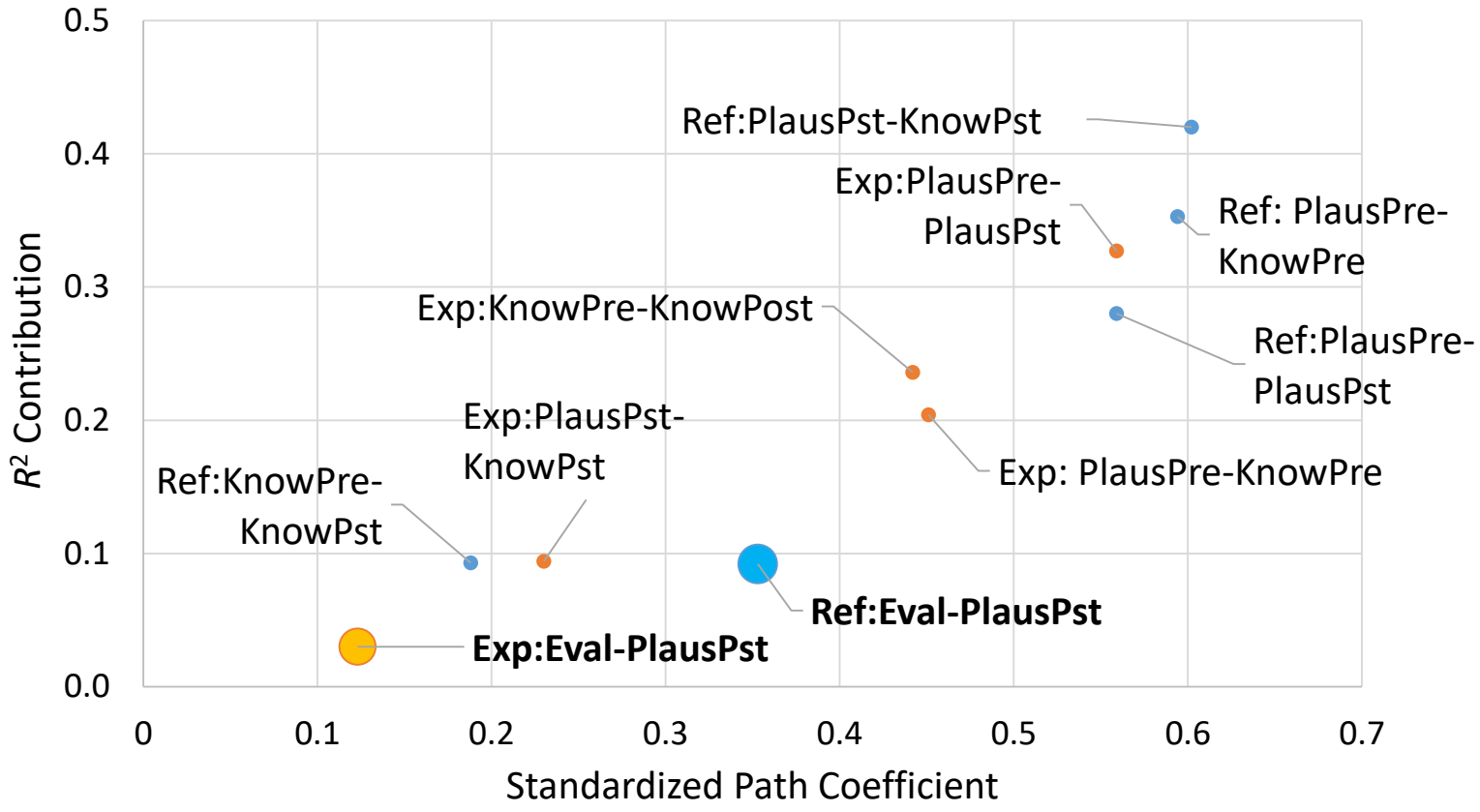
Participants who read the refutation text shifted plausibility and had greater post reading knowledge





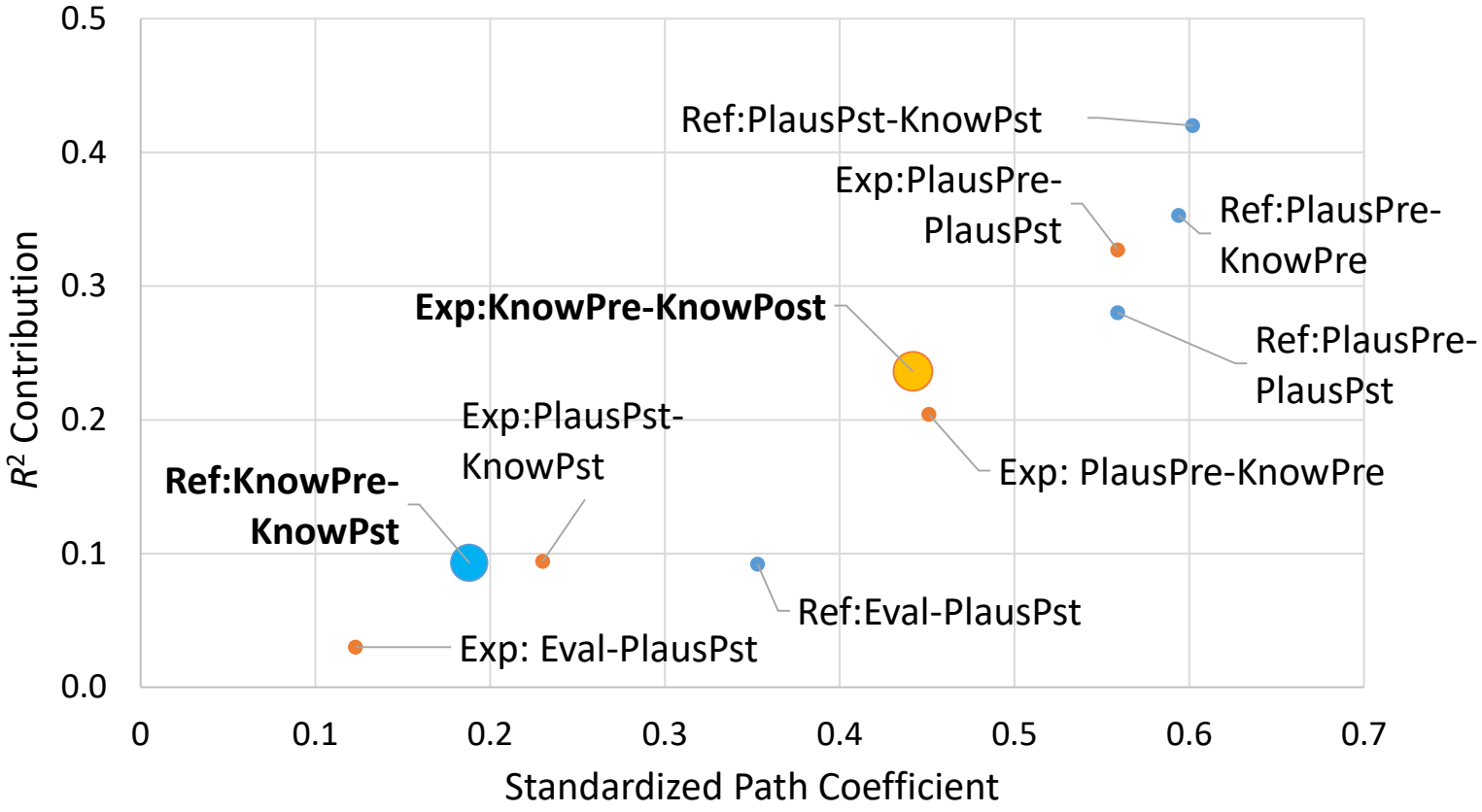
Interaction: $F(2,92) = 3.3$, $p = .04$, $\eta^2 = .067$ (Lombardi et al., 2016b)

Refutation text readers had a stronger connection between evaluation and post reading plausibility,…



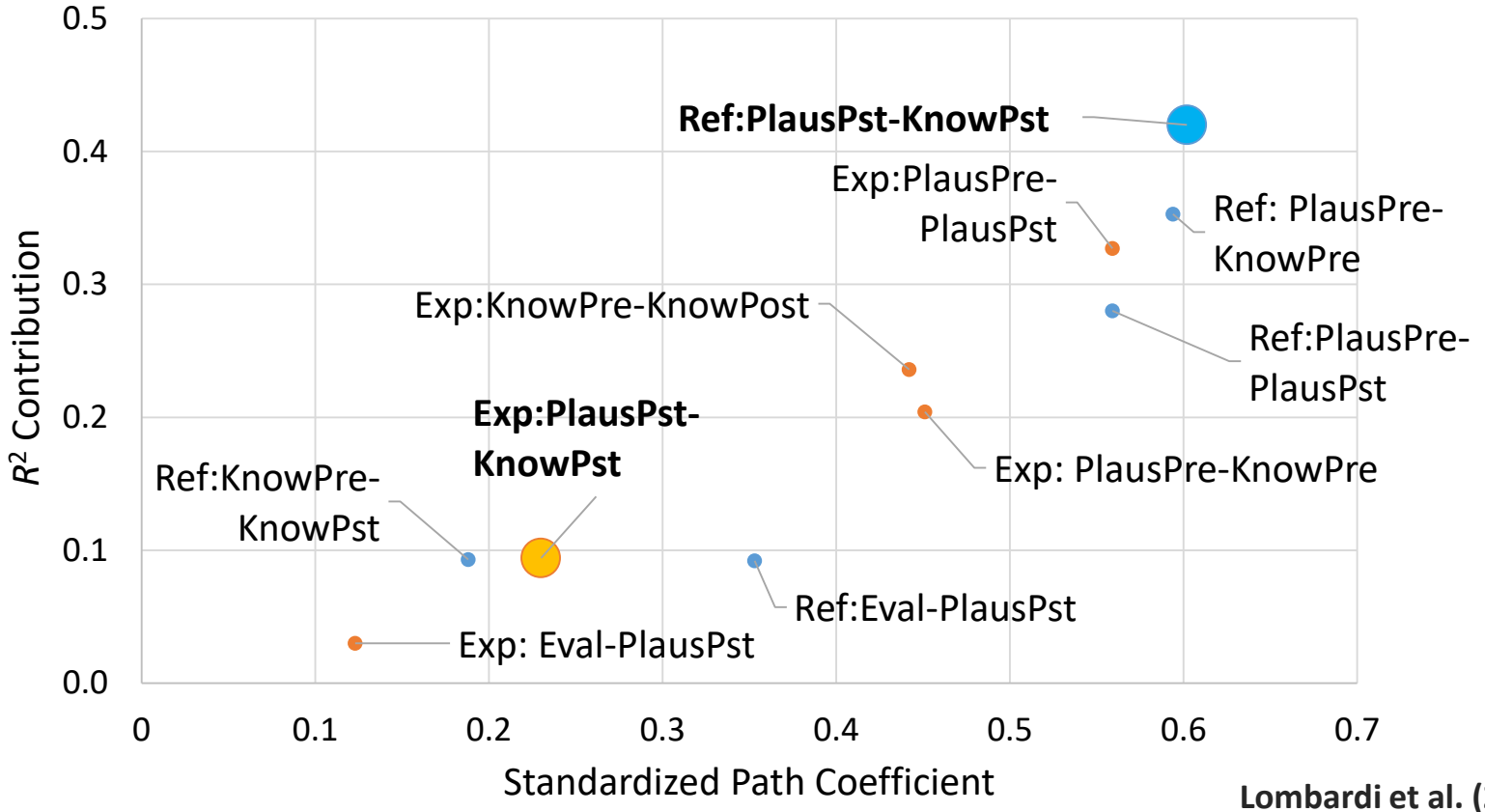
Lombardi et al. (2016b)

...had a weaker connection between prior knowledge and post reading knowledge…



Lombardi et al. (2016b)

…and had a stronger connection between their post reading plausibility judgments and knowledge

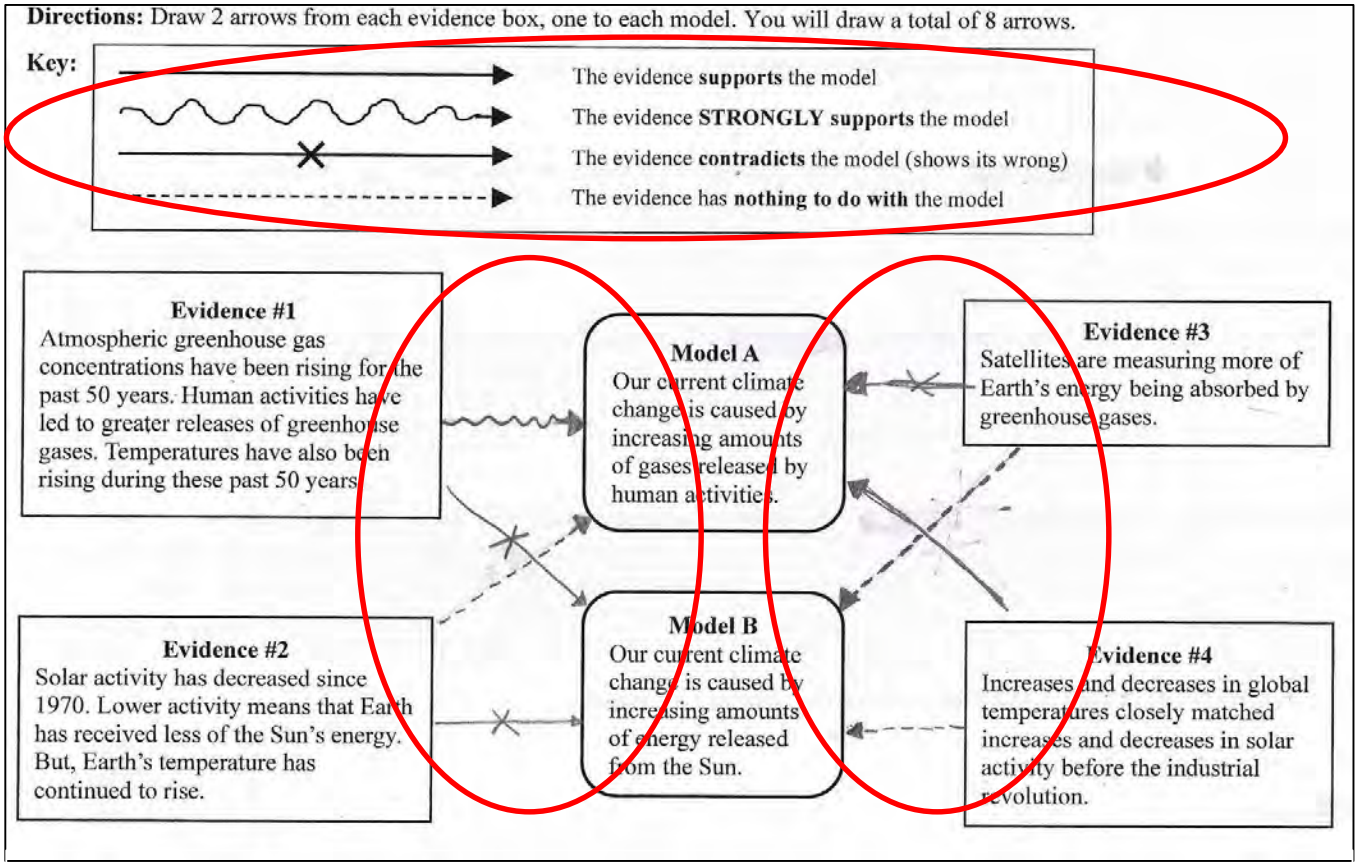


Lombardi et al. (2016b)

However, refutation texts are difficult to design and may be challenging to use effectively in classroom instruction

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

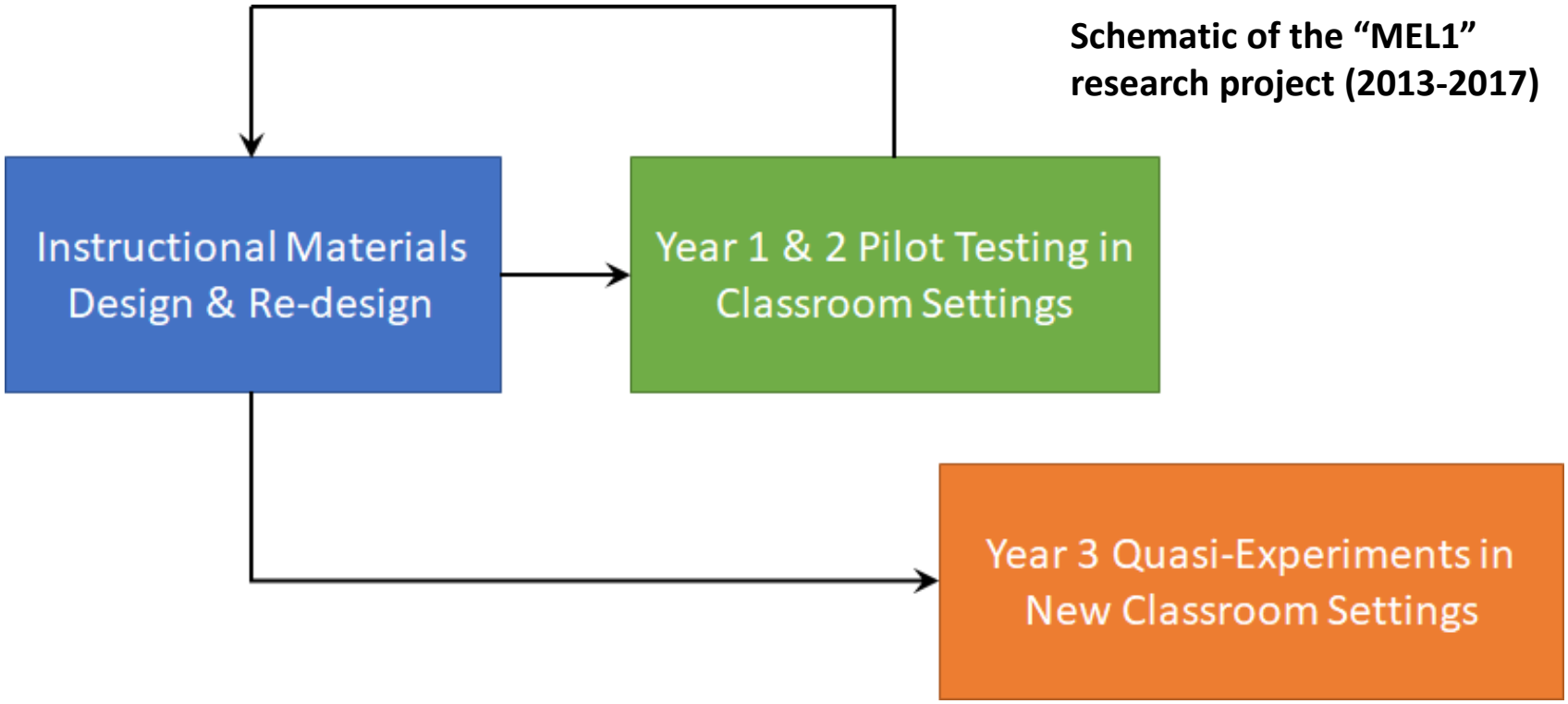
Chinn & colleagues (2012, 2014)



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

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

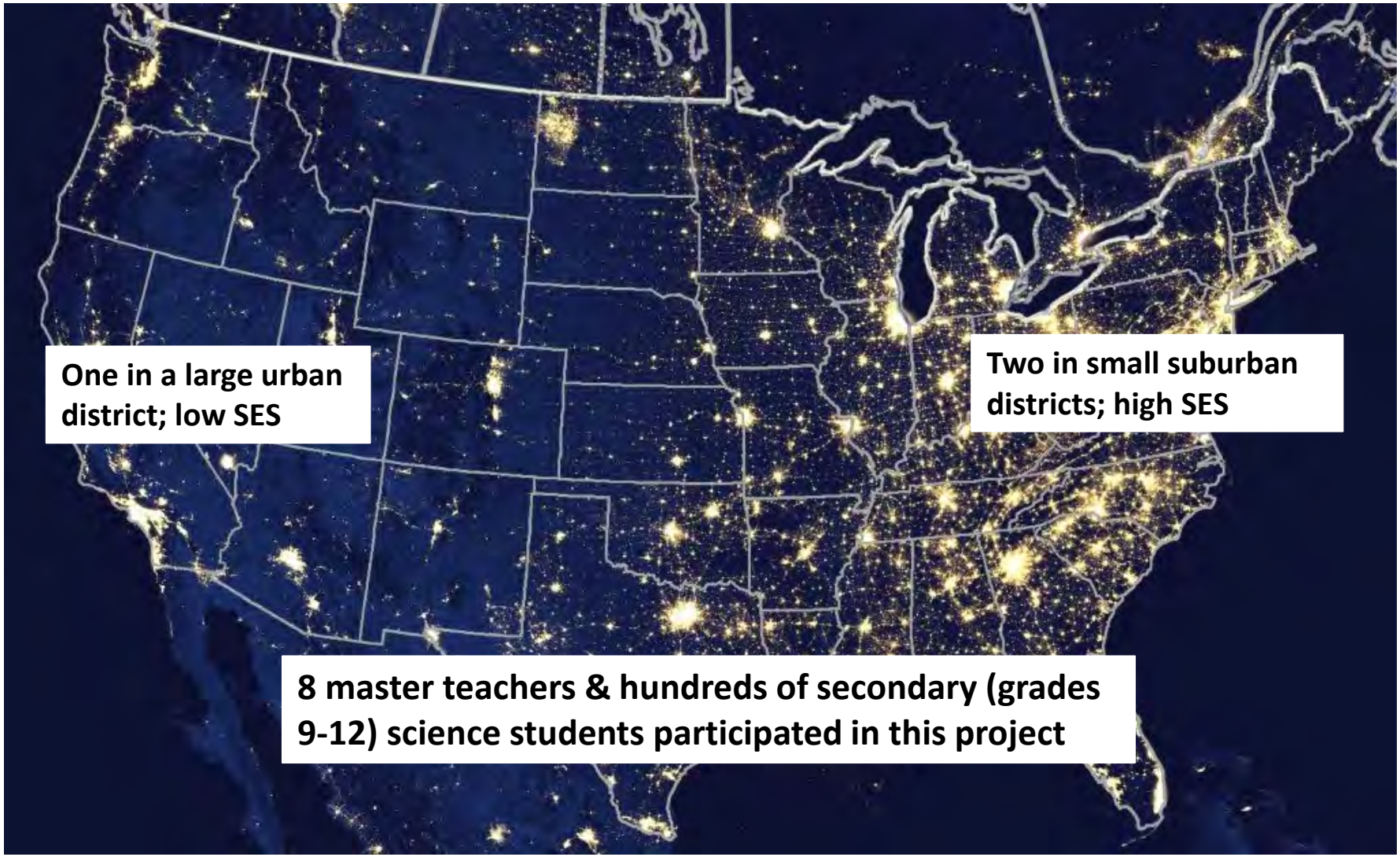
My projects investigate students' evaluations, plausibility, & knowledge about science topics



Schematic of the "MEL1" research project (2013-2017)

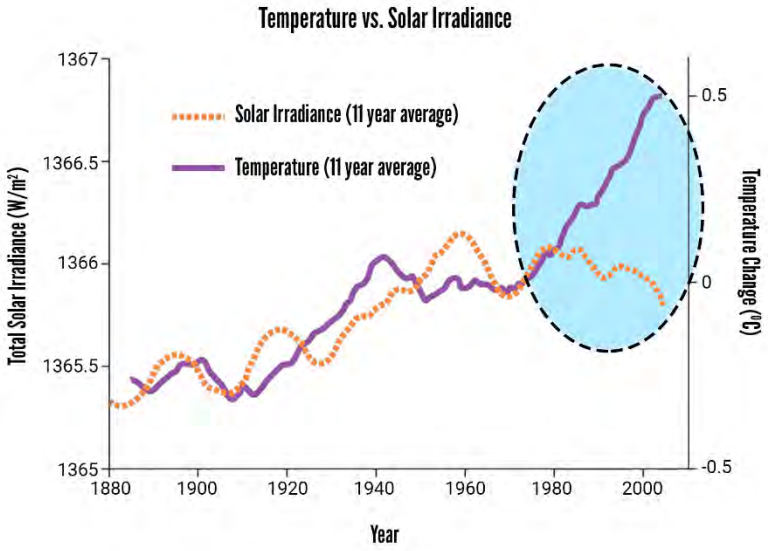
Omnibus research question: How does instruction promoting evaluation result in plausibility reappraisal and knowledge changes about science topics?

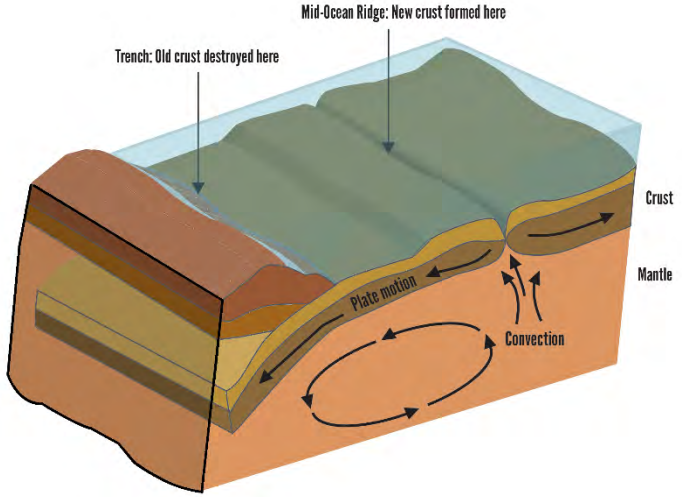
My earlier project involved three school districts from very different parts of the US



Secondary students experienced instruction about four topics during the course of a school year

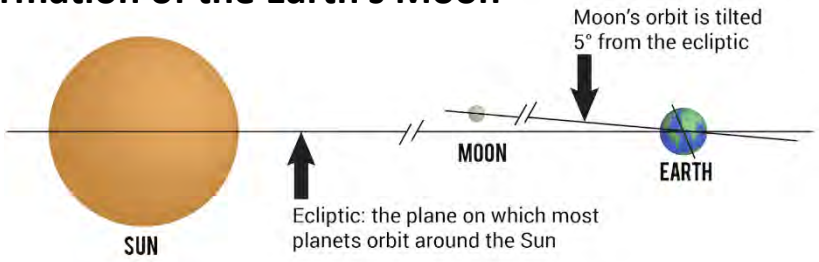
Causes of current climate change

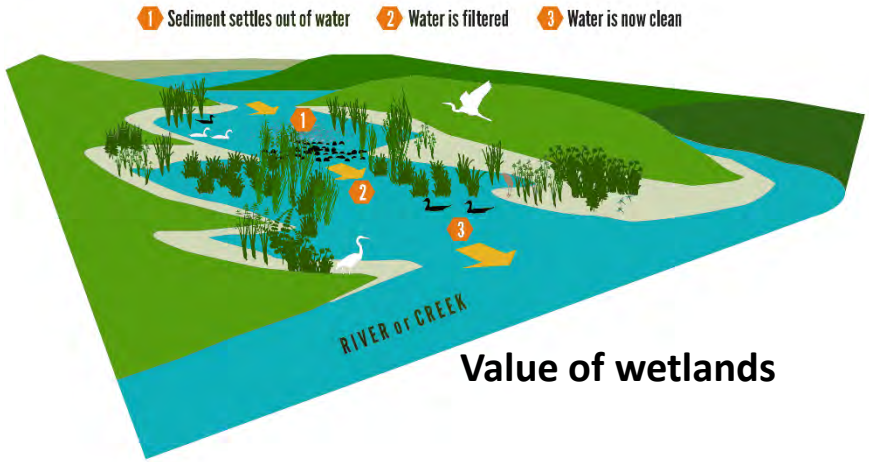




Hydraulic fracturing & earthquakes

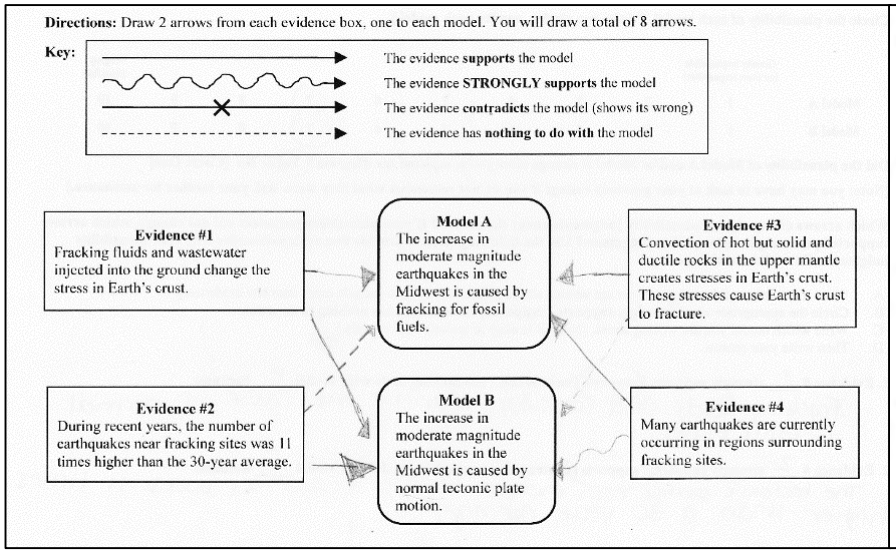
Formation of the Earth's Moon

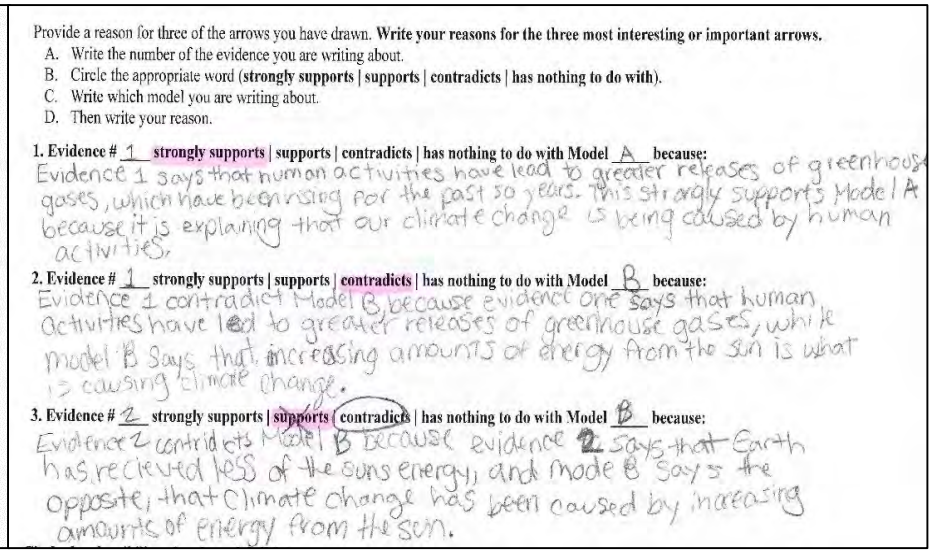




Value of wetlands

In Year 2, a pilot study to investigated the scaffolds' effectiveness





~300 high school students at 4 school locations completed MEL diagrams for all four topics, followed by a written explanation task and other associated activities

Qualitative analyses revealed 4 levels of students' evaluations reflected in the explanation task

Category	Description	Score
Erroneous Evaluation	Explanation contains an incorrect model-to-evidence link and/or is mostly inconsistent with scientific understanding.	1
Descriptive Evaluation	Explanation is correct, but the evidence-to-model link weight states that the evidence has nothing to do with the model. Explanation does not clearly distinguish between lines of evidence and explanatory models.	2
Relational Evaluation	Explanation is correct, with an evidence-to-model link weight of strongly supports, supports, or contradicts as appropriate. Explanation distinguishes between lines of evidence and explanatory models, but does so in a merely associative or correlation manner based on text similarity.	3
Critical Evaluation	Explanation is correct, with an evidence-to-model link weight of strongly supports, supports, or contradicts as appropriate. The explanation reflects deeper cognitive processing that elaborates on an evaluation of evidence and model. Explanation distinguishes between lines of evidence and explanatory models, allows for more sophisticated connections, and concurrently examines alternative models.	4

Lombardi et al. (2016c, 2017)

Students rated the plausibility of two alternative explanatory models about a phenomenon

Case 1: Probabilistic Reasoning

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

Case 2: Plausibilistic Reasoning (common)

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

Case 3: Plausibilistic Reasoning (uncommon)

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

Lombardi et al. (2018a,b)

Short knowledge surveys probed students' understanding for each topic

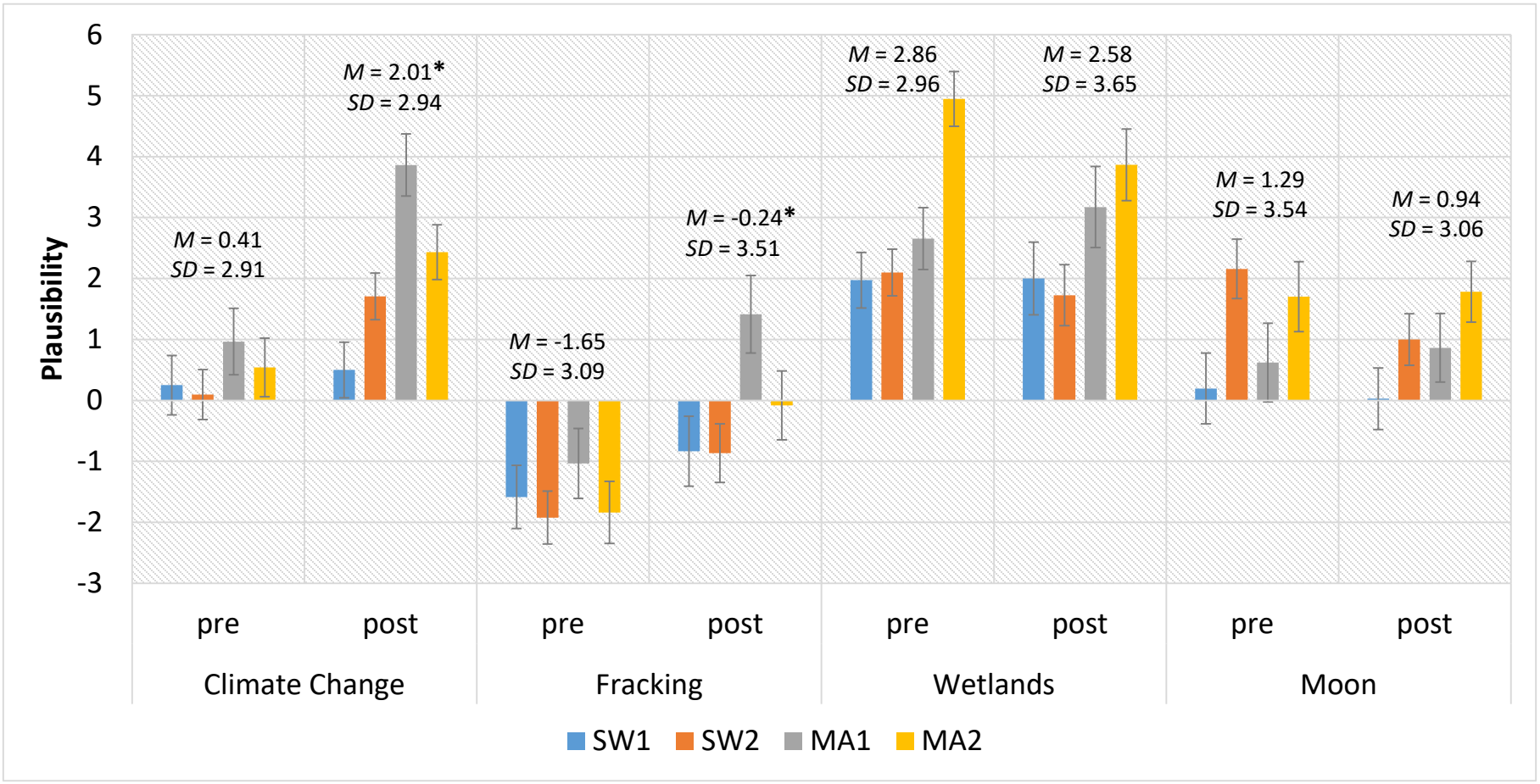
Below are statements about climate change. Rate the degree to which you think that *climate scientists* agree with these statements.

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1. The Sun is the main source of energy for Earth's climate.	A	B	C	D	E
2. *We cannot know about ancient climate change.*	A	B	C	D	E
3. Burning of fossil fuels produces greenhouse gases.	A	B	C	D	E
4. Greenhouse gases absorb some of the energy emitted by Earth's surface.	A	B	C	D	E
5. Earth's climate is currently changing.	A	B	C	D	E

Although short, my research team has calibrated these with longer forms and testing revealed instrument validity for research purposes

Lombardi et al. (2018a,b)

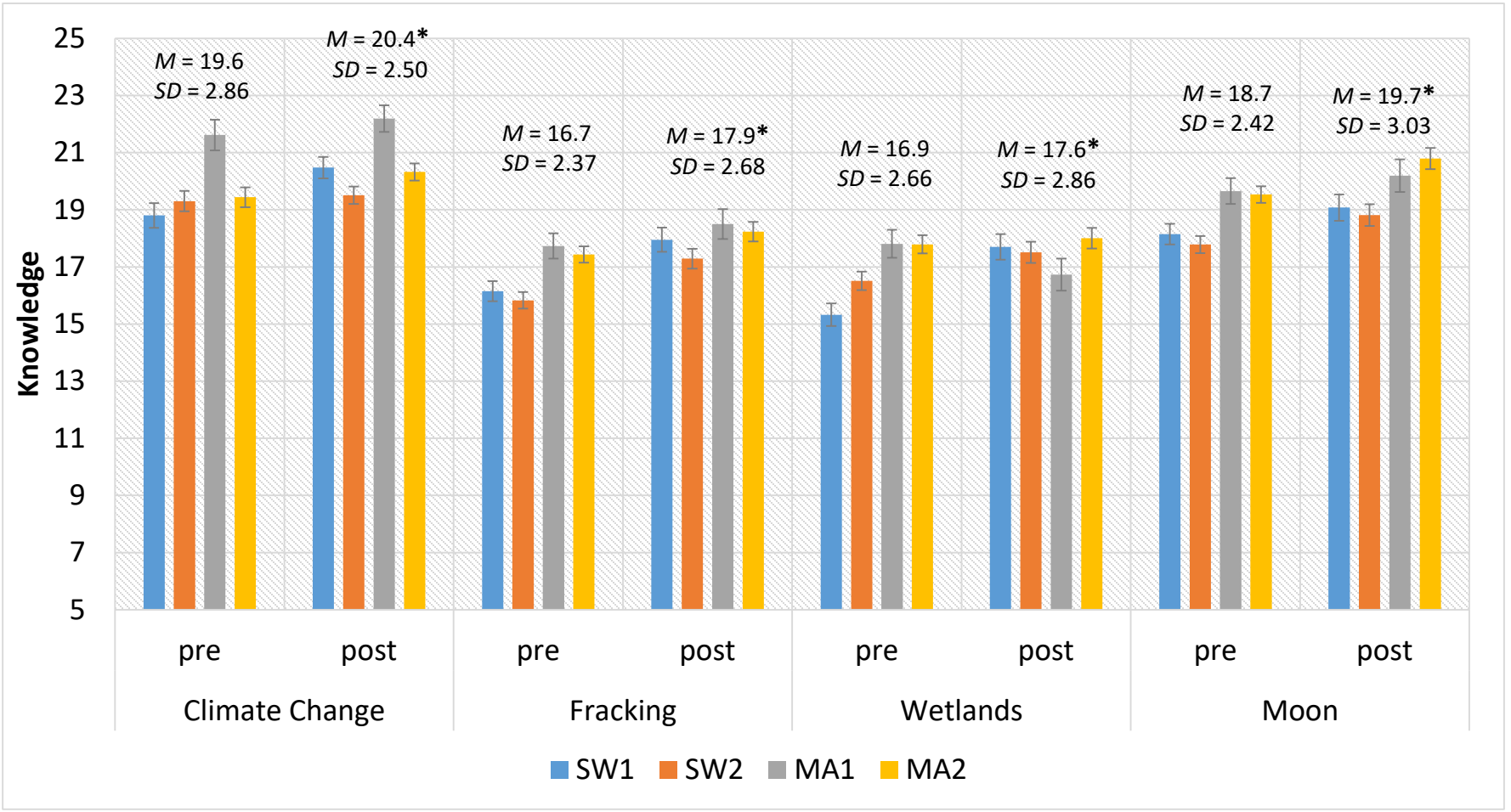
These pilot study results revealed plausibility shifts for some topics (e.g., climate change), but not for others



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

Lombardi et al. (2018a)

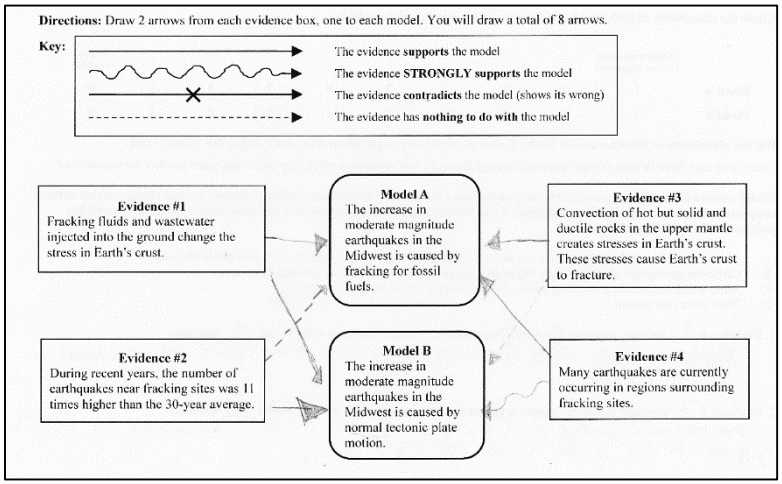
However, all topics showed increases in knowledge



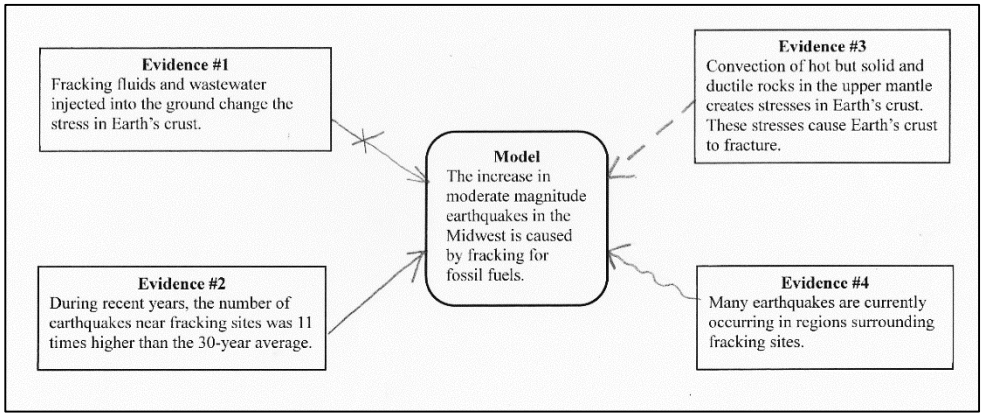
$F(12,546) = 15.1$, $p < .001$, $\eta_p^2 = .251$

Lombardi et al. (2018a)

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

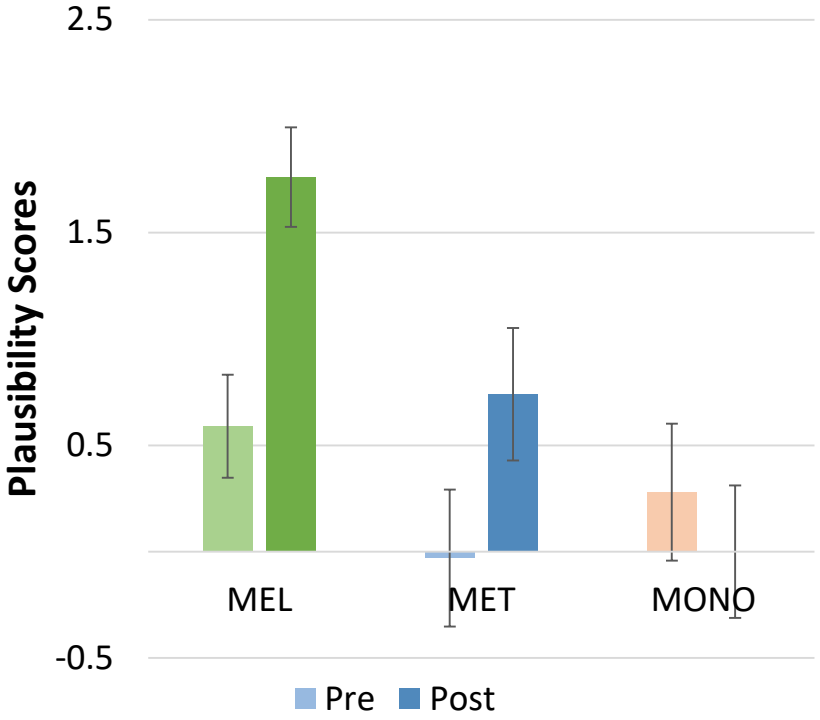
	Model A The increase in moderate magnitude earthquakes in the Midwest is caused by fracking for fossil fuels.	**Model B** The increase in moderate magnitude earthquakes in the Midwest is caused by normal tectonic plate motion.
Evidence #1 Fracking fluids and wastewater injected into the ground change 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

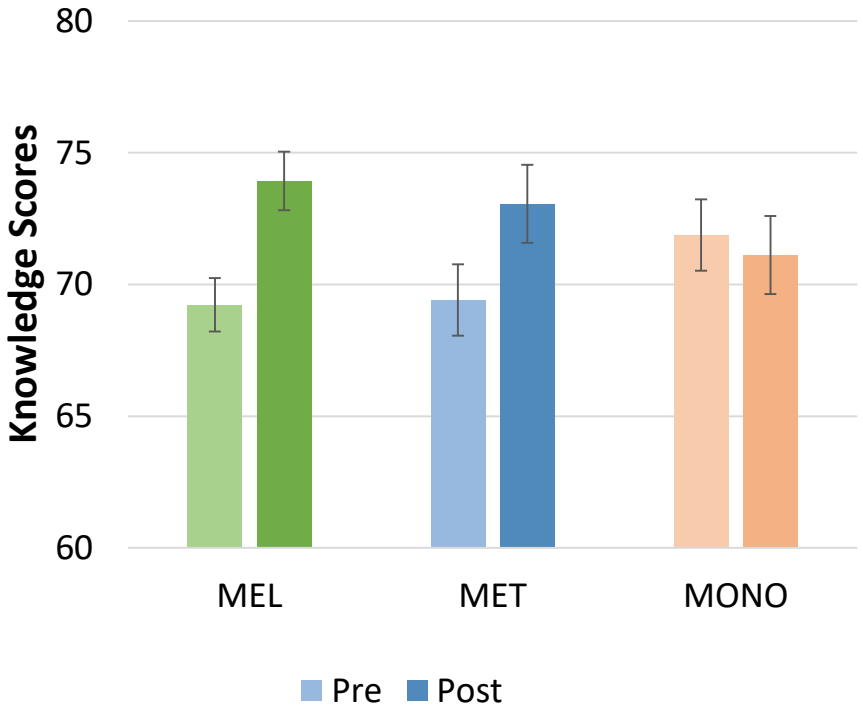
Lombardi et al. (2018b)

Participants' scores showed meaningful plausibility shifts and knowledge increases toward the scientific…

…but only when students simultaneously evaluated lines of evidence and two alternative explanations (Lombardi et al., 2018b)

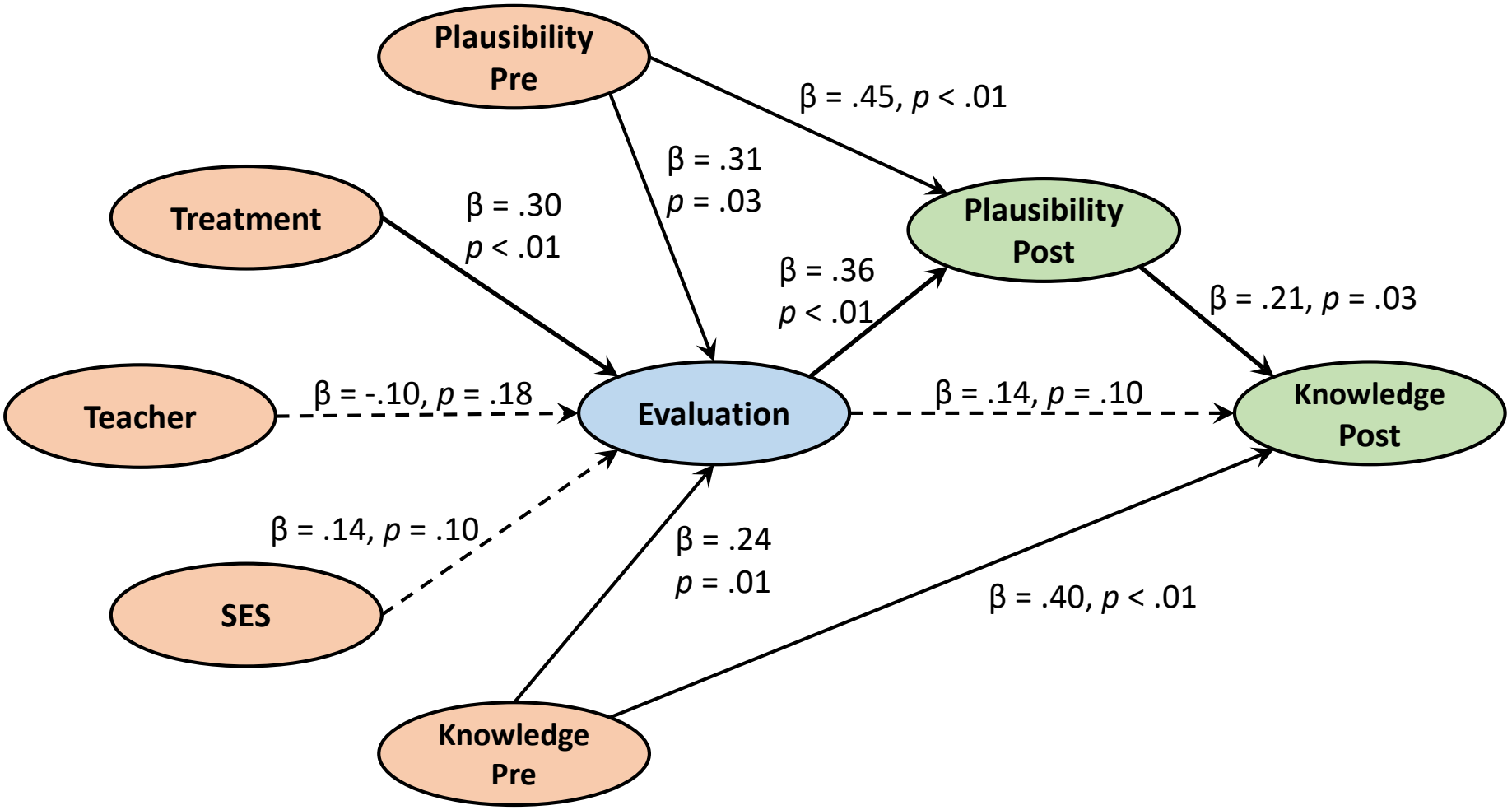


Wilks' λ = .843, $F(2,61) = 5.67$, $p = .006$, medium effect size ($\eta^2 = .157$)



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

Deeper evaluations facilitated participants' plausibility reappraisals and greater knowledge



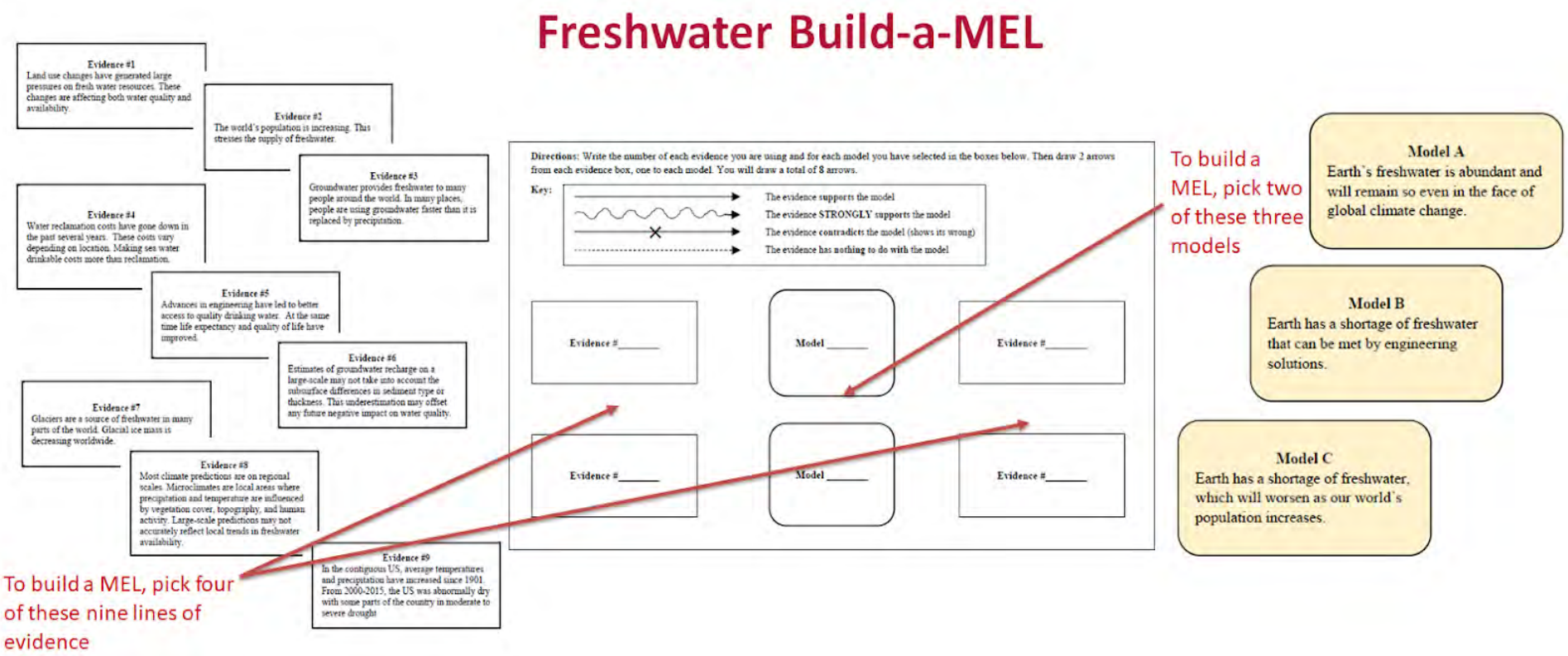
GoF = .437 (large explanatory power); APC = .265, *p* < .001; ARS = .330, *p* < .001; AVIF = 1.12; AFVIF = 1.46; and NLBCDR = 1.0; Lombardi et al. (2018b)

These results are aligned with and complementary to several empirical studies and recent theory…

…(e.g., Lombardi et al., 2013; Lombardi et al., 2016a,b,c; Lombardi et al., 2018b)

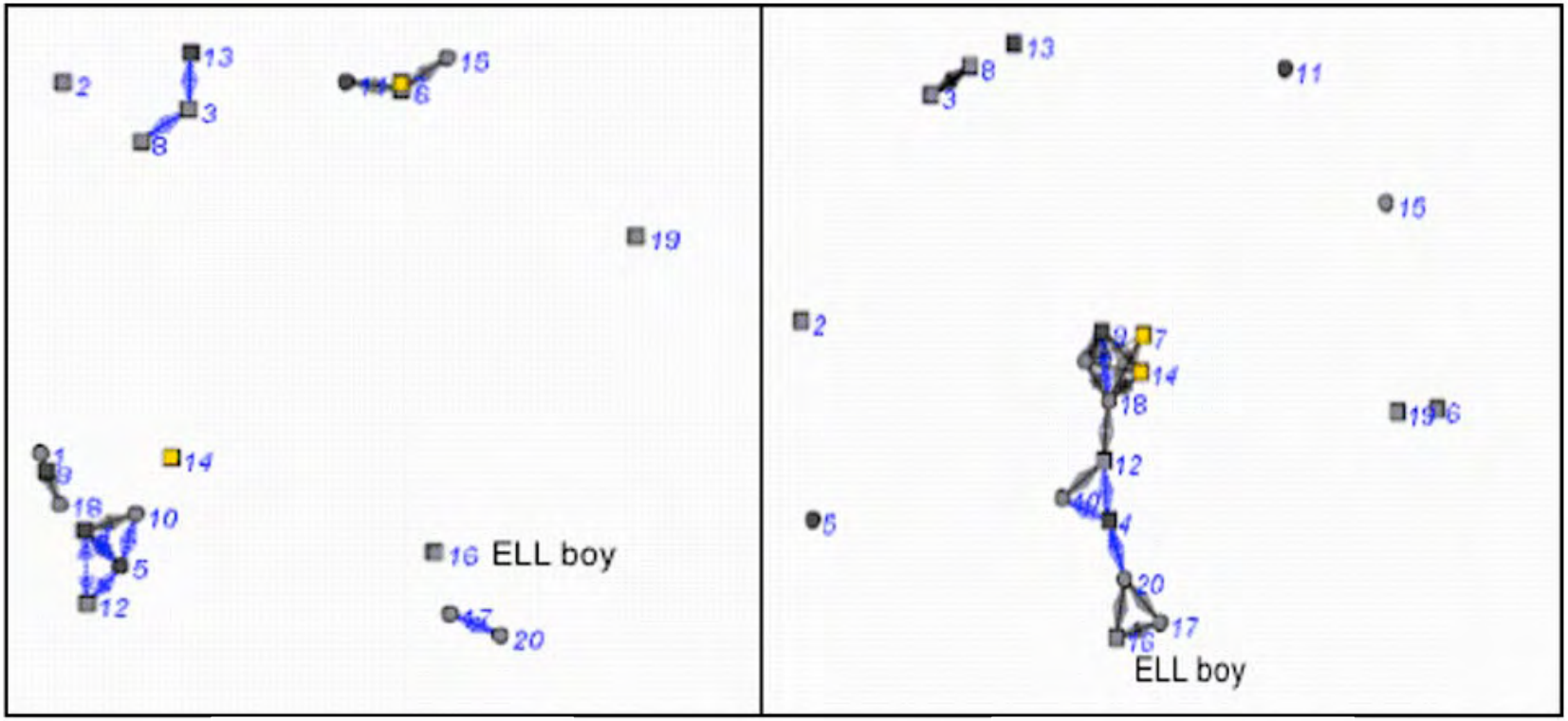
But I am unsatisfied, because unpublished results suggest that students are not transferring their evaluative thinking outside of the classroom context

My current project—MEL2—examines 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; Pickering, 1995)

MEL2 includes observations of classroom discourse to gauge development of epistemic agency



Observation 1 Observation 2

Example of a social network analysis diagram showing students' change in epistemic discourse during classroom learning (Ryu & Lombardi, 2015)

In summary…

…researchers and teachers need to help learners more critically evaluate & reappraise their epistemic judgments…

…and development of critical thinking practices are essential for all so that we can equitably address current and future local, regional, and global challenges

Acknowledgements and Thank You!

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