

# Instructional Scaffolds to Shift Students' Epistemic Evaluations toward the Scientific

- 1 Sediment settles out of water
- 2 Water is filtered
- 3 Water is now clean



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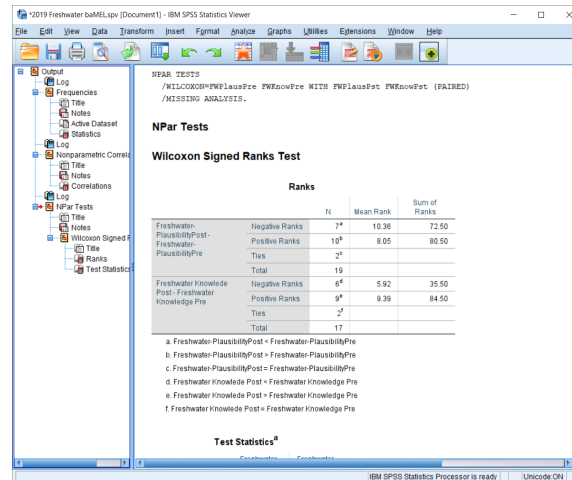
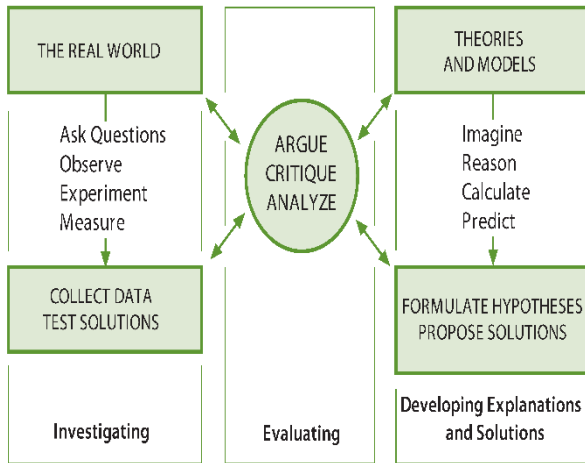
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# This presentation will overview our recent research about students' understanding of socio-scientific topics



**Theoretical and empirical foundations**

**Our present studies**

**Implications and the road ahead**

**Pressing and complex local and global challenges requires increased scientific literacy...**



**...and to deepen scientific literacy, students must understand both (a) what scientists know and (b) how scientists come to know what they know**



**However, students may find scientific explanations to be implausible**



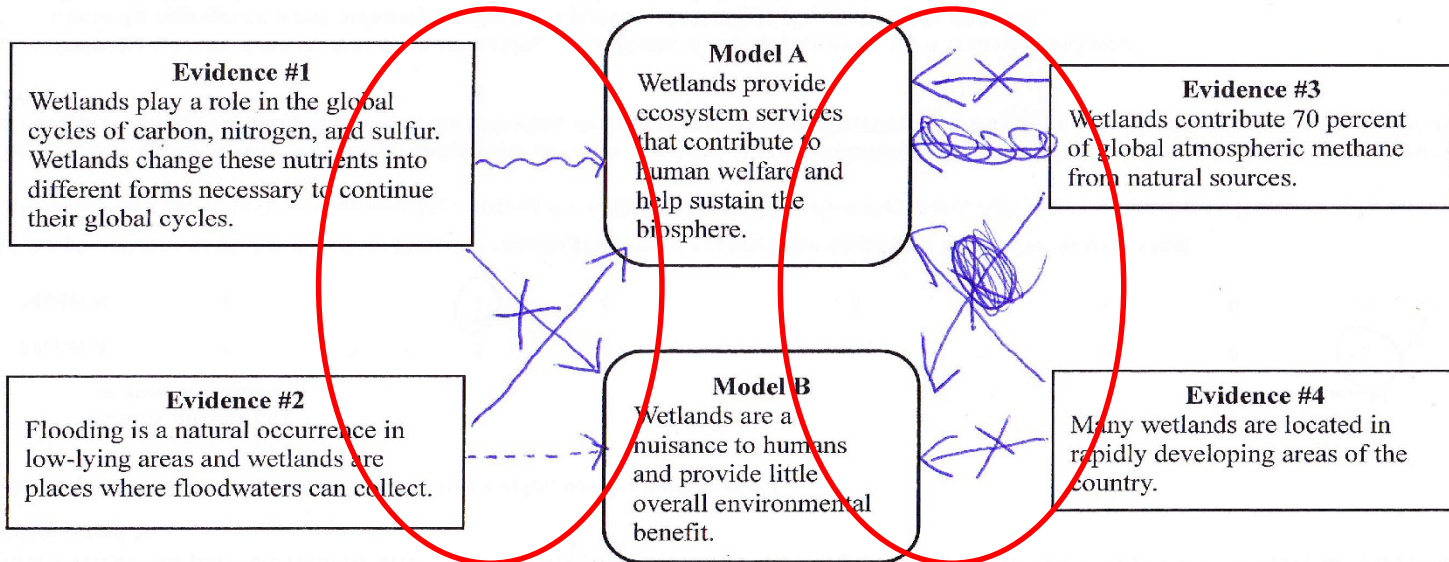
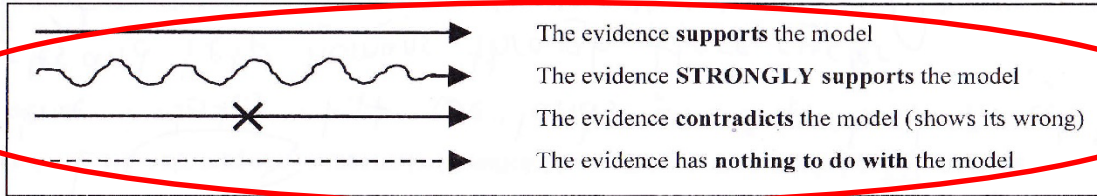
**Epistemic judgments (e.g., plausibility) may be formed through automatic cognitive evaluations with little purposeful thinking (Lombardi et al., 2016)**

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

Chinn & colleagues (2012, 2014)

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

**Key:**

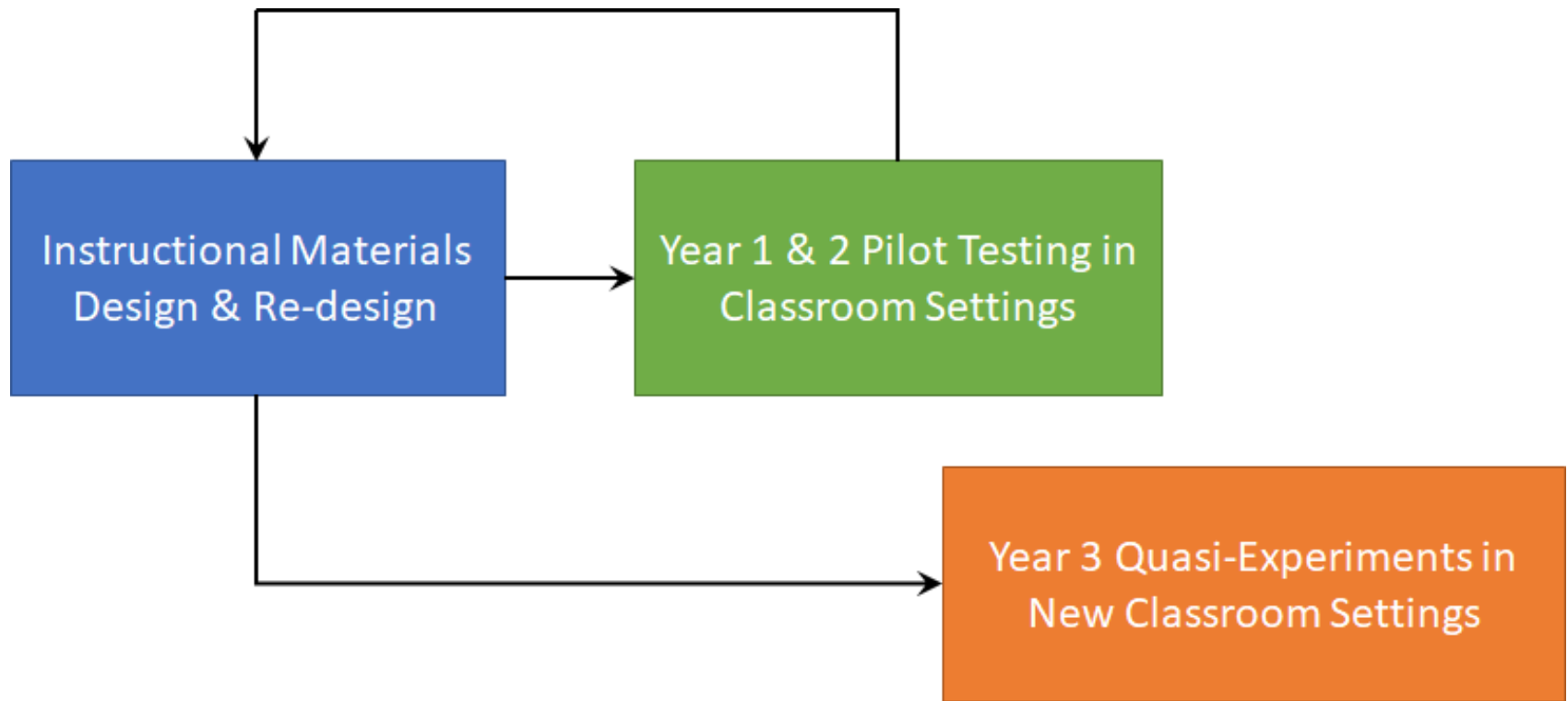


Example of student completed Model-Evidence Link (MEL) diagram

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

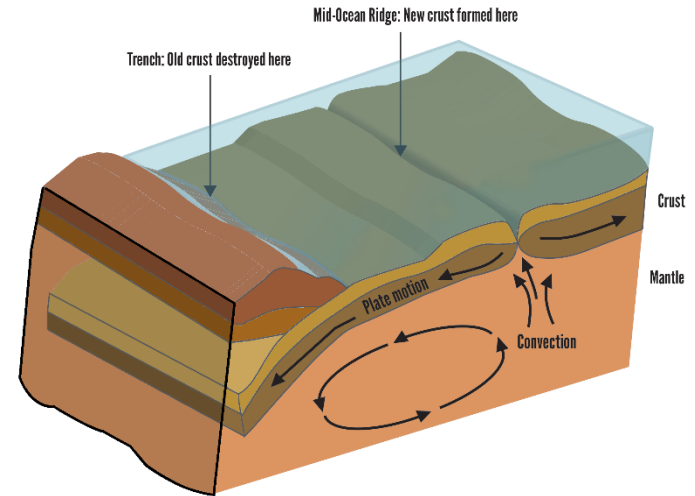
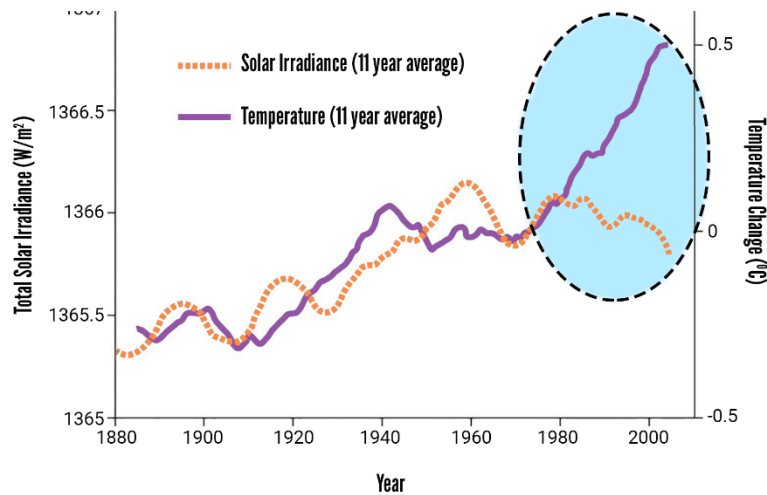
# Our projects investigate students' evaluations, plausibility, & knowledge about socio-scientific topics

Schematic of our first research project (2013-2017)



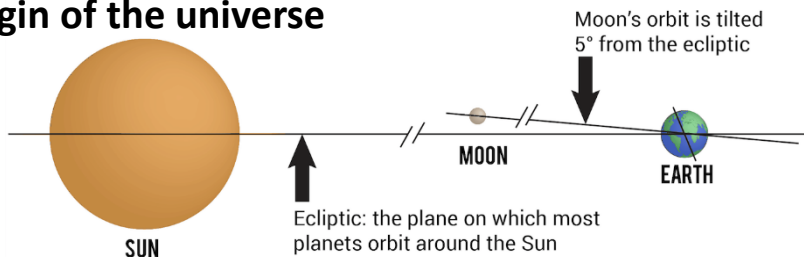
# Secondary students experienced repeated instruction about socio-scientific topics during a full school year

## Causes of current climate change & connections to extreme weather events

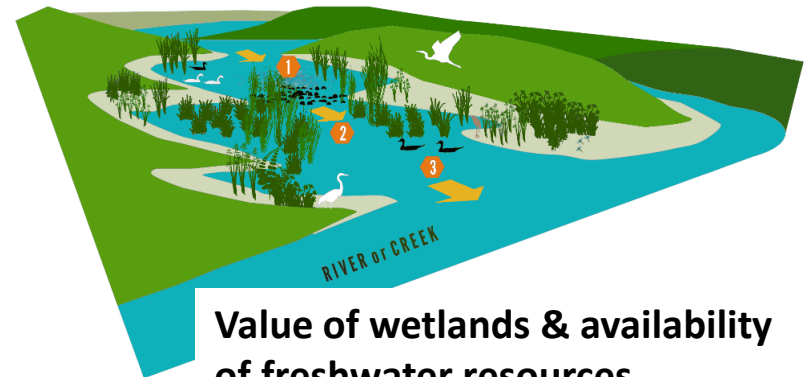


## Hydraulic fracturing & earthquakes

## Formation of the Earth's Moon & origin of the universe



- 1 Sediment settles out of water
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## Value of wetlands & availability of freshwater resources



# Our current project examines scaffolds with the potential to 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
- X ← The evidence contradicts the model (shows its wrong)
- The evidence has nothing to do with the model

Evidence # _____	Model _____	Evidence # _____
Evidence # _____	Model _____	Evidence # _____

**To build a MEL, pick two of these three models**

**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.

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)



# Study 1 compared students' learning between the two types of MEL activities

**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**  
Wetlands play a role in the global cycles of carbon, nitrogen, and sulfur. Wetlands change these nutrients into different forms necessary to continue their global cycles.

**Evidence #2**  
Flooding is a natural occurrence in low-lying areas and wetlands are places where floodwaters can collect.

**Evidence #3**  
Wetlands contribute 70 percent of global atmospheric methane from natural sources.

**Evidence #4**  
Many wetlands are located in rapidly developing areas of the country.

**Model A**  
Wetlands provide ecosystem services that contribute to human welfare and help sustain the biosphere.

**Model B**  
Wetlands are a nuisance to humans and provide little overall environmental benefit.

**Directions:** Write the number of each evidence you are using and for each model you have selected in the boxes below. You will draw a total of 8 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**  
Land use changes have generated large pressures on fresh water resources. Some changes are affecting both water quality and availability.

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

**Evidence #3**  
Contaminants provide freshwater to many people around the world. In many places, people are using groundwater from this. It is recharged by precipitation.

**Evidence #4**  
When reclamation costs have gone down in the past several years, there has been a trend to expand irrigation. This has led to a decline in groundwater.

**Evidence #5**  
Advances in engineering have led to better access to quality drinking water. At the same time the opportunity cost of this has increased.

**Evidence #6**  
Estimates of freshwater recharge in a large-scale may not take into account the additional differences in recharge type of locations. This underestimates any effect and these require support in water quality.

**Evidence #7**  
Climate is a source of freshwater in many parts of the world. Climate is now a decreasing worldwide.

**Evidence #8**  
Most large populations are in arid and semi-arid areas. These areas have high evaporation and precipitation are influenced by geographic, topographic, and human factors. Large-scale precipitation can not accurately reflect local trends in freshwater availability.

**Evidence #9**  
In the mid-1970s, the average temperature and precipitation have decreased since 1910. From 2000-2012, the US has decreased by 10% with some parts of the country in decline to water drought.

**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 two of these three models**

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

**H: the build-a-MEL would result in greater levels of evaluation, scientific shifts in plausibility, & increased knowledge about water resources than the preconstructed-MEL**



**N = 76 grade 6-12 students at two different schools, 1 in Georgia & 1 in New Jersey**

# All students completed a written explanation task after completing their diagram or table

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.

Using a rubric developed by Lombardi et al. (2017), we score tasks for evaluation on a scale from 1 to 4, with 1 = erroneous, 2 = descriptive, 3 = relational, and 4 = critical

# Students rated the plausibility (pre and post) of two or three alternative explanatory models for 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

We calculate plausibility scores as the scientific explanation rating minus the alternative model(s) rating, with scores ranging from +9 (highly scientific) to -9 (non-scientific)

# Short knowledge surveys probed students' understanding for each topic pre and post instruction

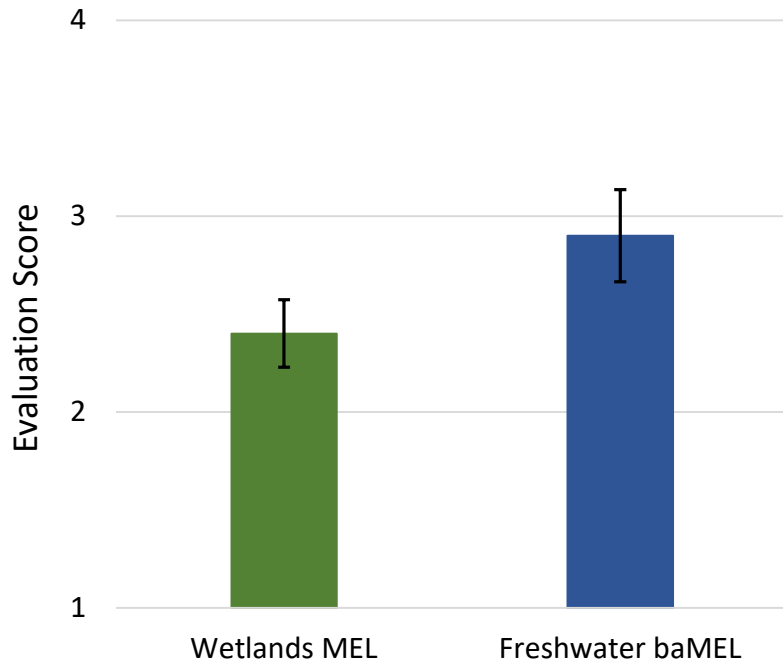
Below are statements about freshwater resources. Rate the degree to which you think that *hydrologists* agree with these statements.

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1. Water reclamation makes contaminated water safe for humans to use.	A	B	C	D	E
2. Engineers will solve current shortages of freshwater.	A	B	C	D	E
3. Freshwater is abundant and will remain so even in the face of global climate change.	A	B	C	D	E
4. Land use decisions affect Earth's surface, but have little impact on the water cycle.	A	B	C	D	E
5. Technology advances have made water safer for human use.	A	B	C	D	E
6. Groundwater recharge rates are similar from place to place because soils are generally uniform.	A	B	C	D	E
7. Global temperatures have increased. But, there has not been an overall decrease in global glacial ice.	A	B	C	D	E
8. Microclimates have various levels of precipitation. This affects how much water is available for human use.	A	B	C	D	E
9. Over the past 100 years, lower amounts of rainfall have occurred across the US. This means that greater amounts of land have been affected by drought in the last 20 years.	A	B	C	D	E
10. Current shortages of freshwater will get worse around the globe as world population increases.	A	B	C	D	E
11. Climate change and increasing populations will lead to more freshwater shortages.	A	B	C	D	E

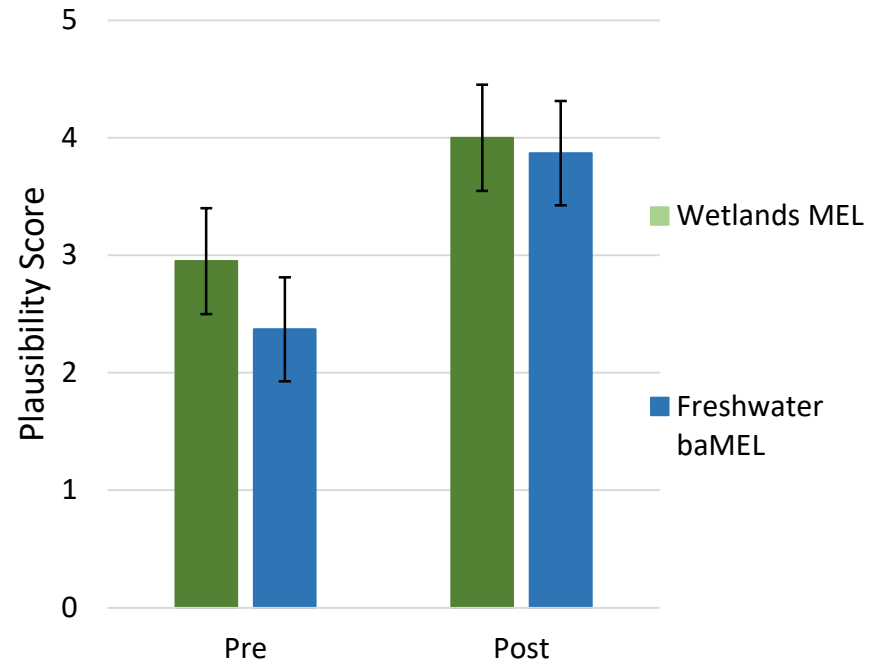
**Possible knowledge scores range from 5 = very low to 55 = very high**



# The build-a-MEL resulted in greater levels of evaluation and slightly more pronounced shifts in plausibility



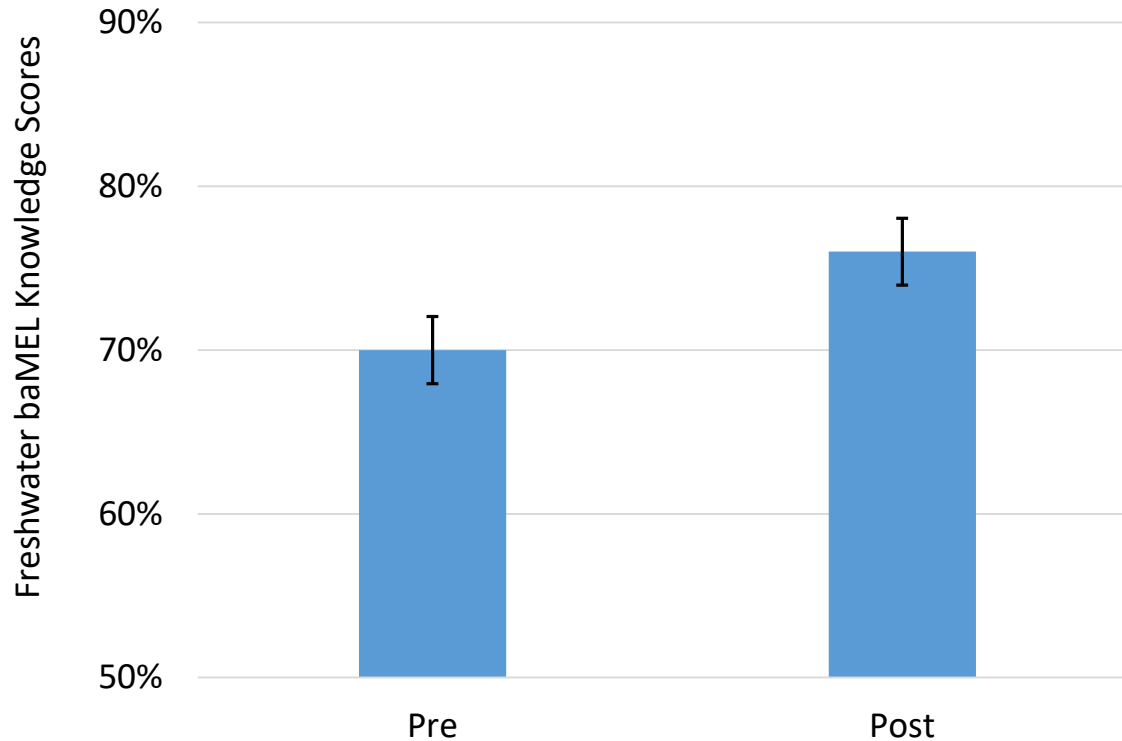
Wilcoxon Signed Ranked Test,  $z = 1.17$



$z = 2.24$  (Freshwater build-a-MEL)  
 $z = 1.88$  (Wetlands pre-constructed MEL)

The build-a-MEL had ~1 category higher evaluation scores than the pre-constructed MEL. Plausibility shifts were ~+1.5 & +1 categories for the build-a-MEL & pre-constructed MEL, respectively

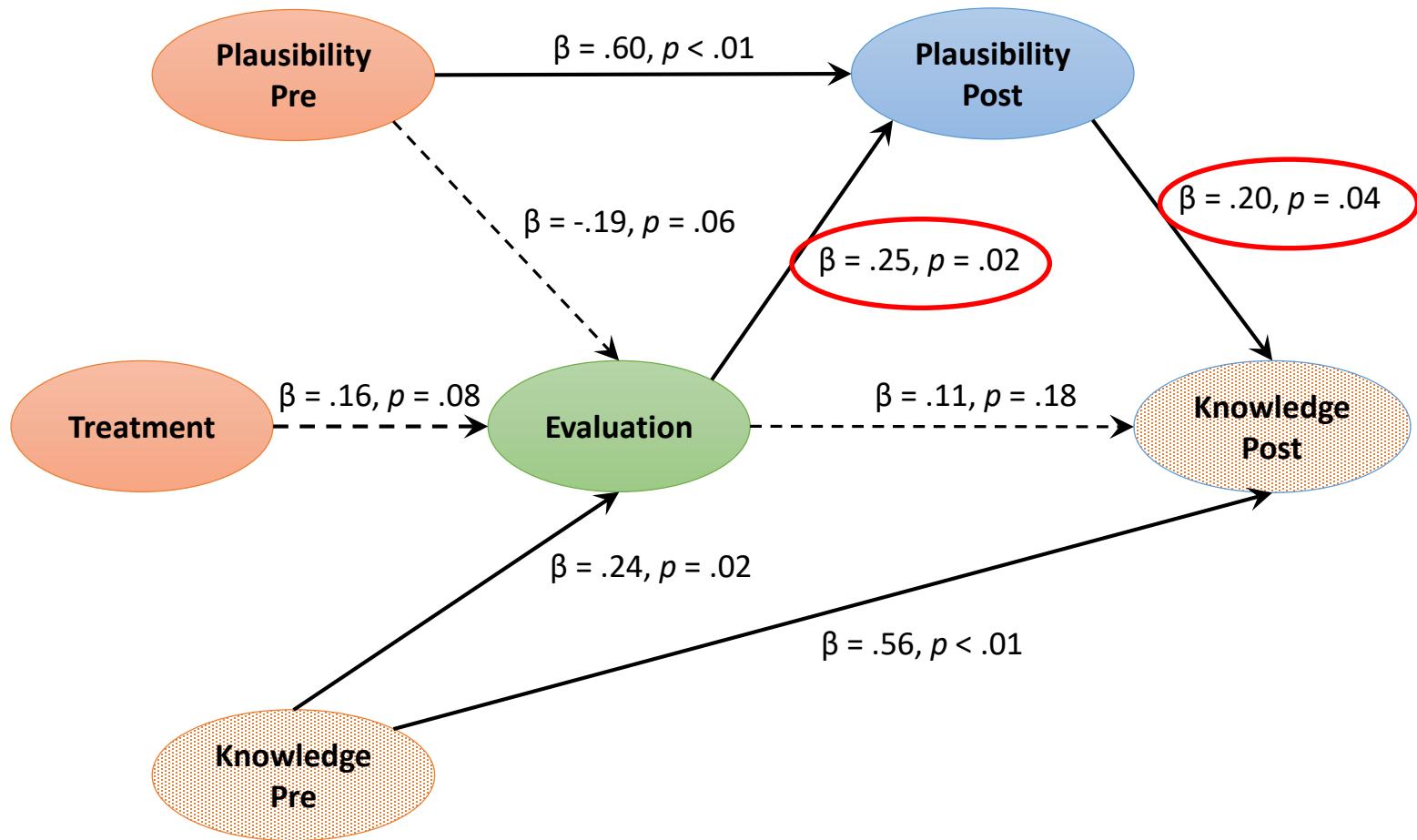
# The build-a-MEL resulted in increased knowledge about freshwater resources



$t(75) = 4.46, p < .001, d = 0.51$ , medium effect size

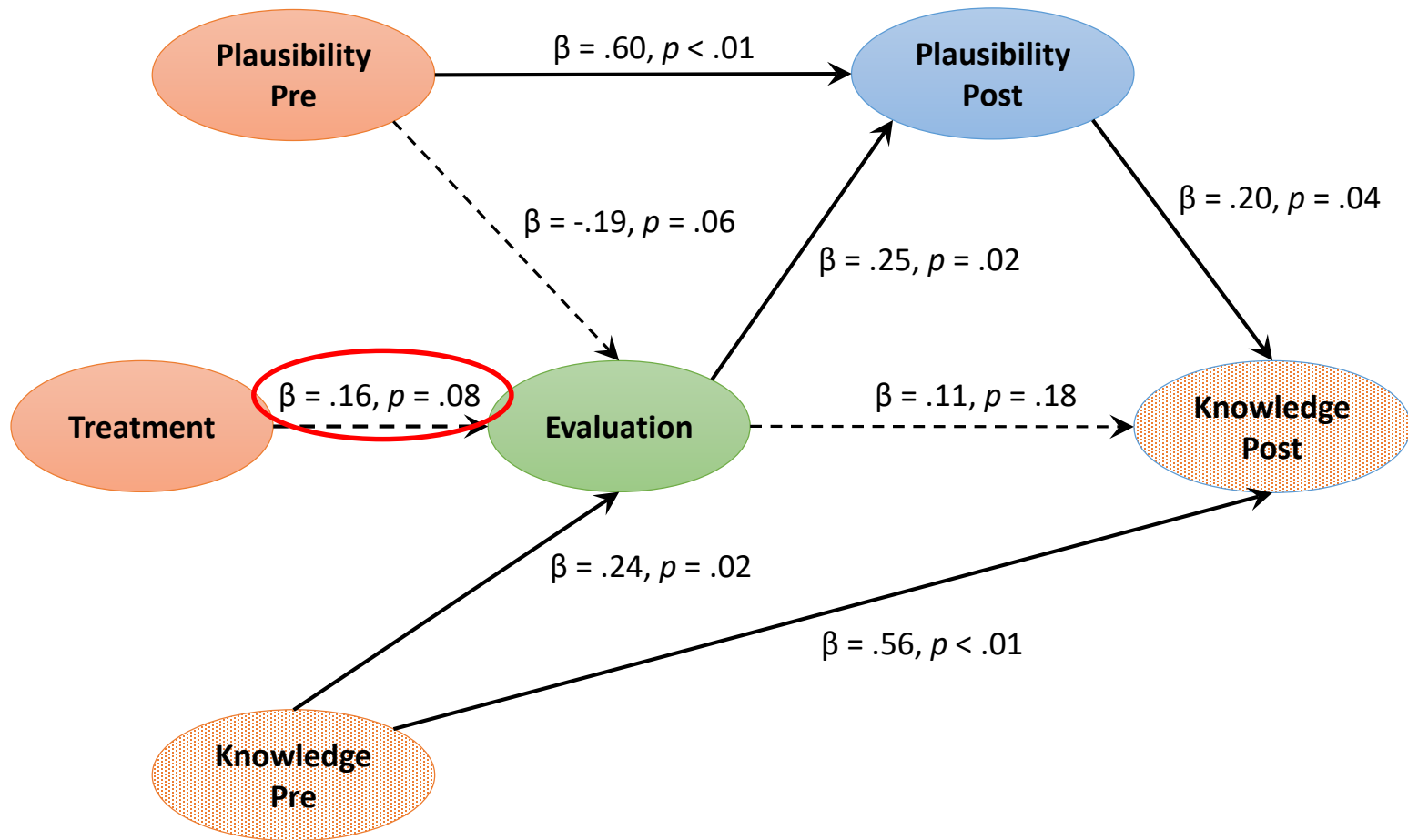
**Pre knowledge was about 70% correct and post knowledge was about 76% correct (i.e., knowledge increased about 6% over 90 minutes of instruction time)**

These pilot data suggest that greater levels of evaluation influence plausibility and knowledge



GoF = .562 (large explanatory power), ARS = .316

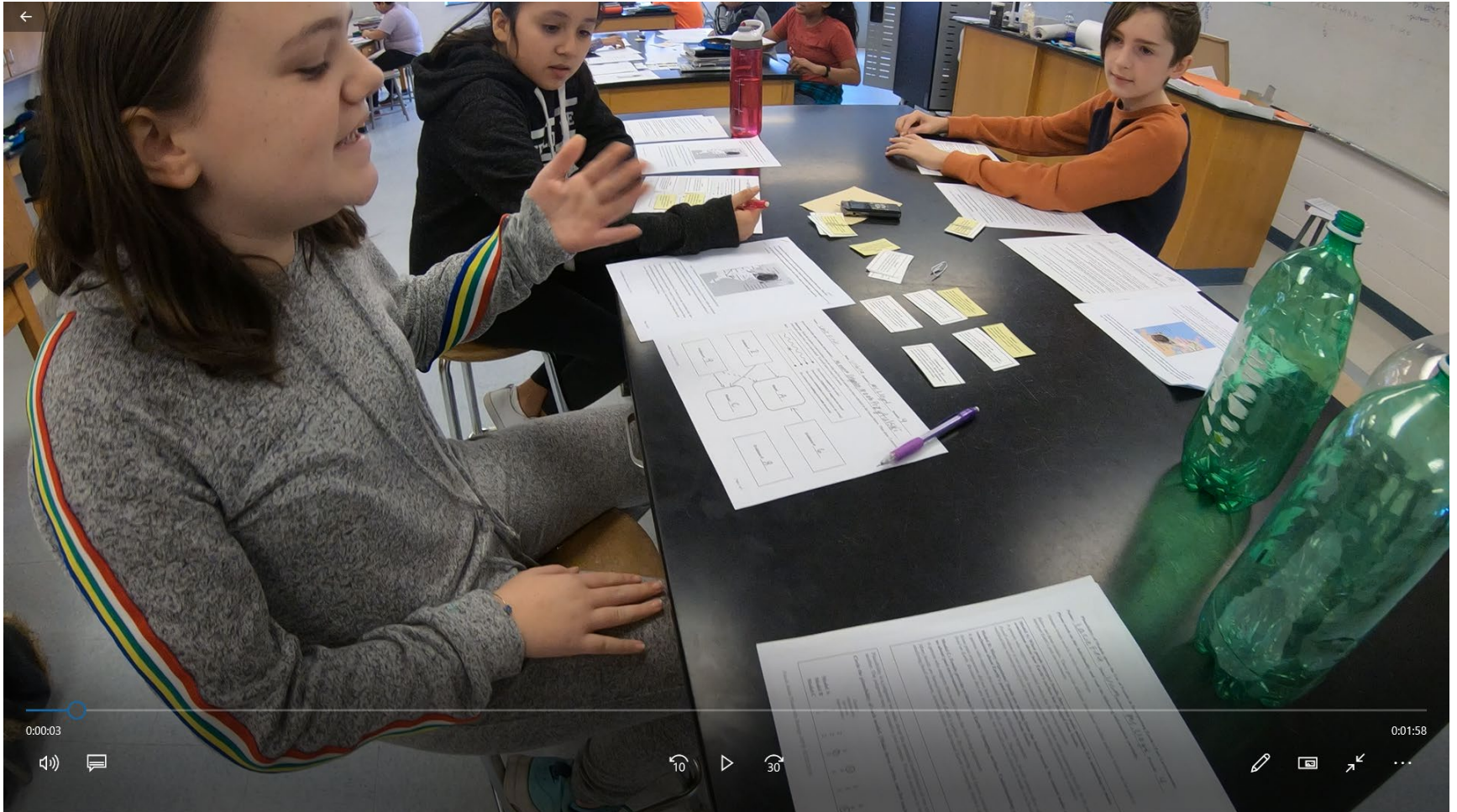
However, we are not seeing a meaningful advantage of the build-a-MEL over the pre-constructed MEL



GoF = .562 (large explanatory power), ARS = .316



# Study 2 qualitatively analyzed video and audio data to examine students' conceptual agency during instruction



## Evidence of conceptual agency included: (a) initiating claims, (b) delegating tasks, and (c) arguing from evidence

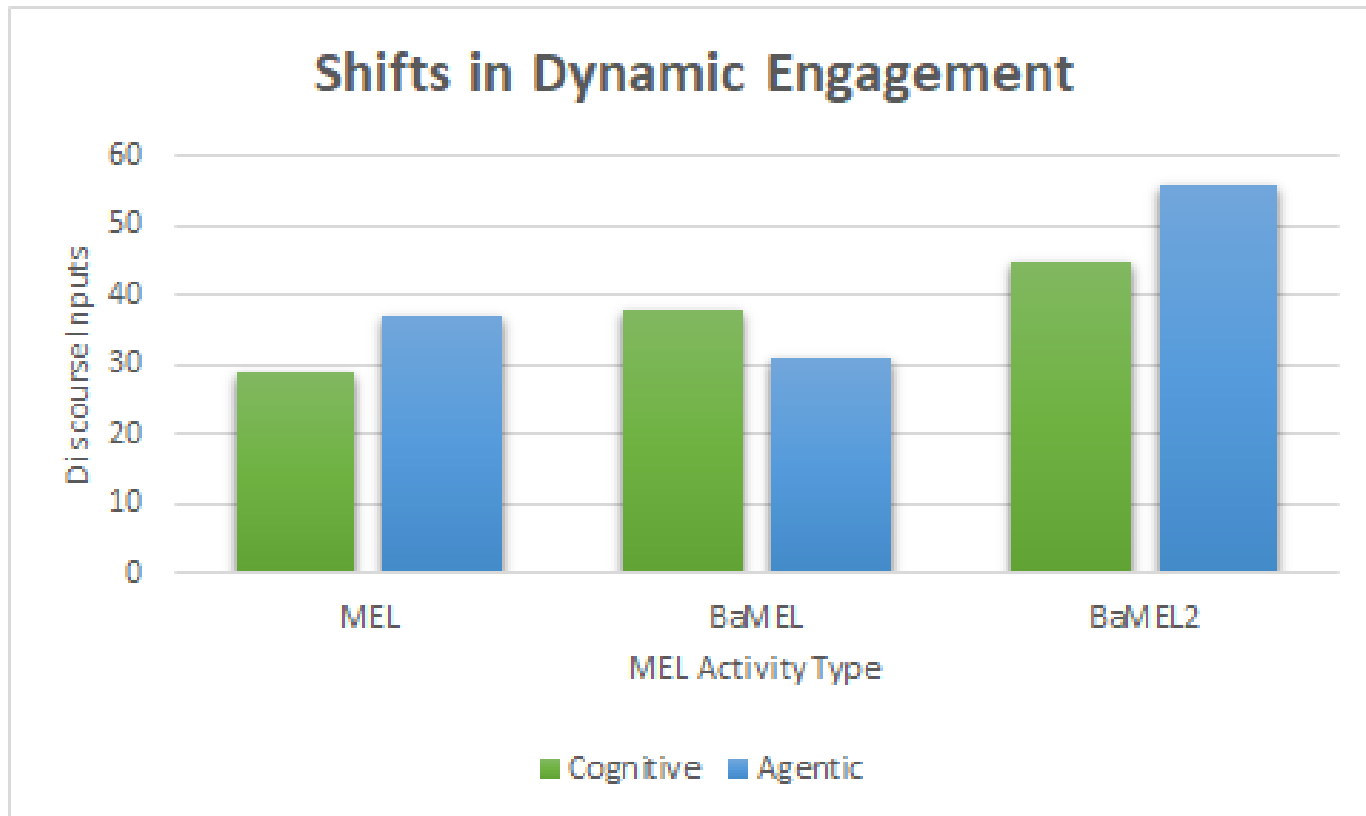
**Ray (pseudonym):** Ok, ok guys lets focus. So we have model A and model C right? So lets read model A and model C again. Model A. When people interpret fossils they often make mistakes. Its misleading to make conclusions about how Earth's surface has changed from fossils. Right?

**Ray:** Right that's a very important piece too of information too. So let's go onto to...uhhh 4. So...ahhhh...so who did 4. I know I didn't... [S4] you must have right?

**S3:** 19,000 years old. Here it says.... Ok So these coral reefs have been found like really down under water. But they need sunlight and sunlight can't go through the water.

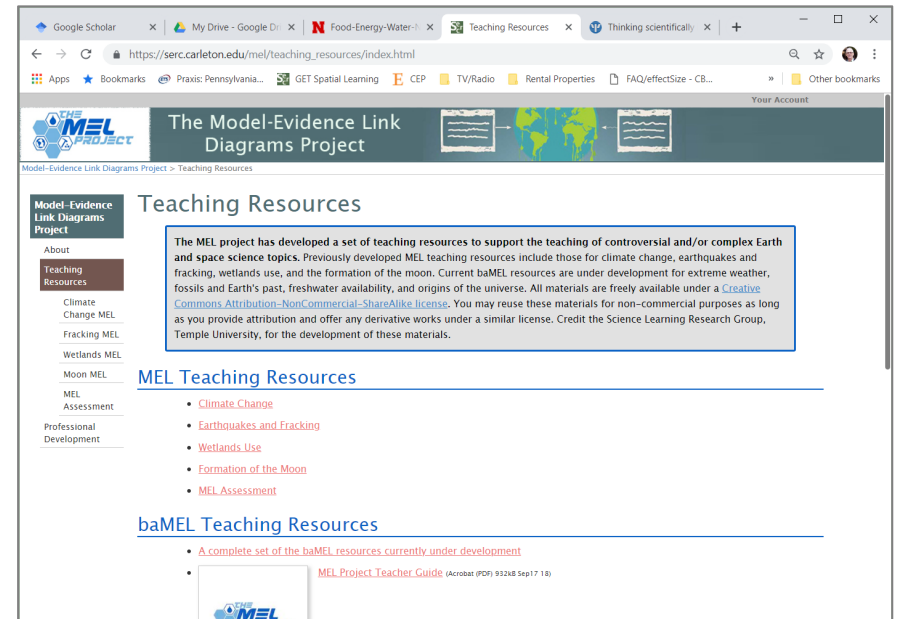
**Ray:** No. It can't go until a certain point.

# A single-student case study revealed increased core conceptual agency during classroom interactions



Higher inputs of cognitive and agentic engagement potentially suggest increased of conceptual agency

Currently we have completed 2 years of data collection and preparing to collect more in the 3<sup>rd</sup> and 4<sup>th</sup> years



Our team is currently examining and analyzing incoming data

Please stay tuned and visit our websites early and often

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

<http://sciencelearning.net>



## 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