

Evaluating Explanations about Water Resources: Scaffolds to Shift Students' Epistemic Judgments toward the Scientific

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



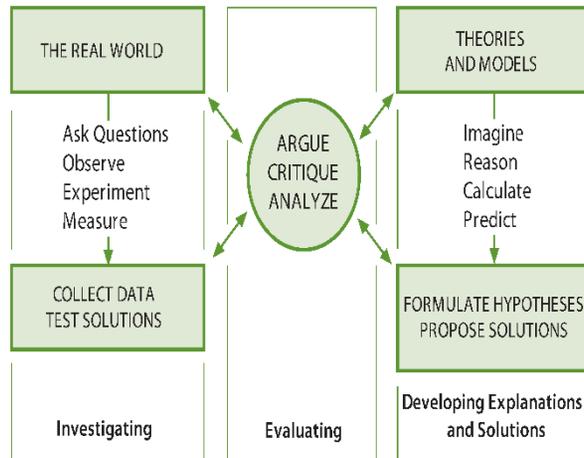
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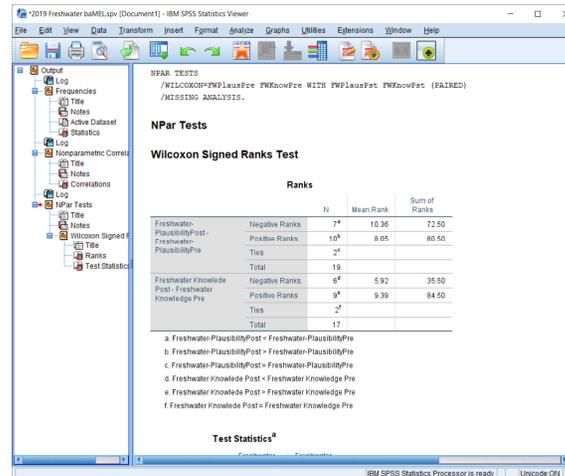
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This presentation will overview our recent research about students' understanding of water resources



Theoretical and empirical foundations

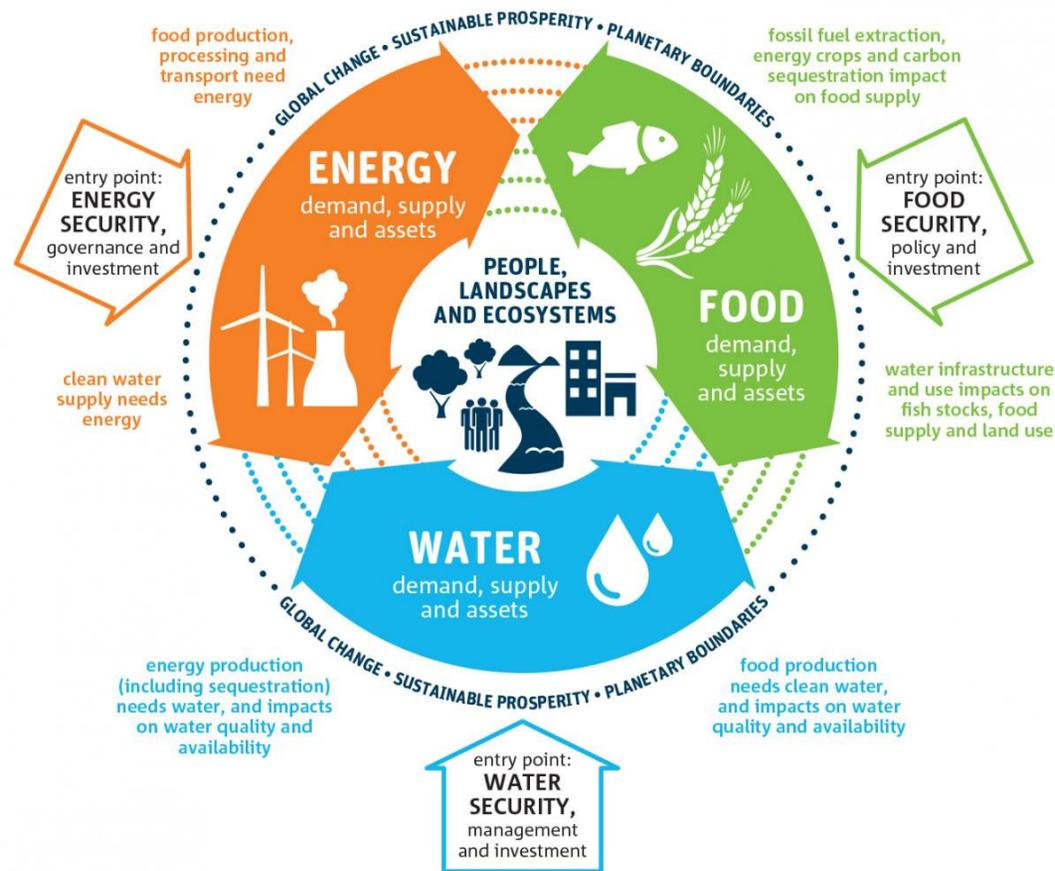


Our present study



Implications and the road ahead

The Food Energy Water (FEW)-Nexus is a framework to address issues with human-natural systems



There is rapidly growing worldwide interest in research about education and discourse around the FEW-Nexus (Forbes et al., 2018)

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



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

However, students may find scientific explanations to be implausible

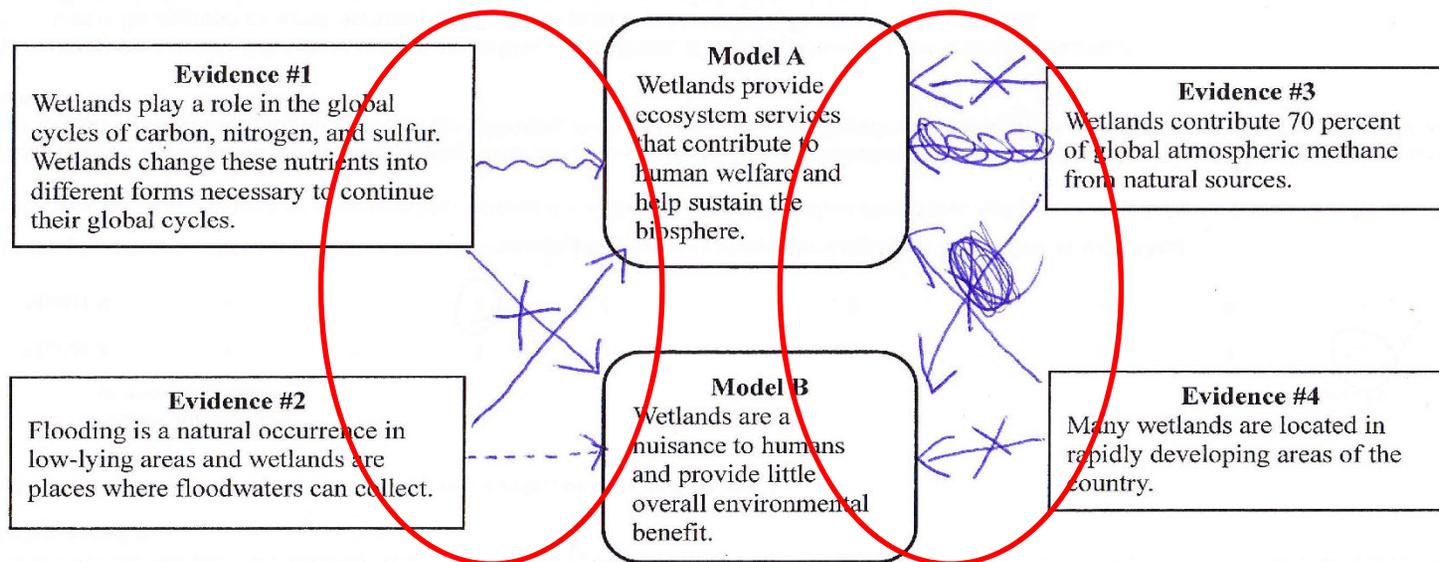
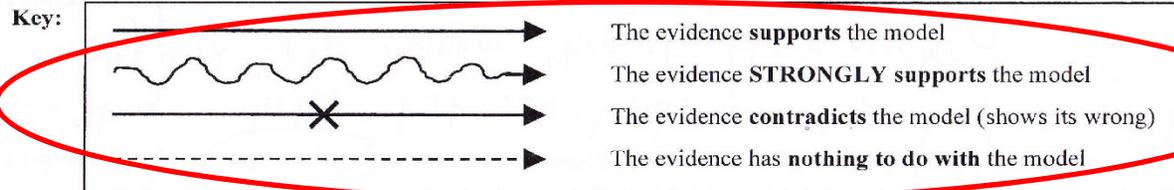


Epistemic judgments (e.g., plausibility) may be formed through automatic cognitive evaluations with little purposeful thinking (Lombardi et al., 2016)

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.

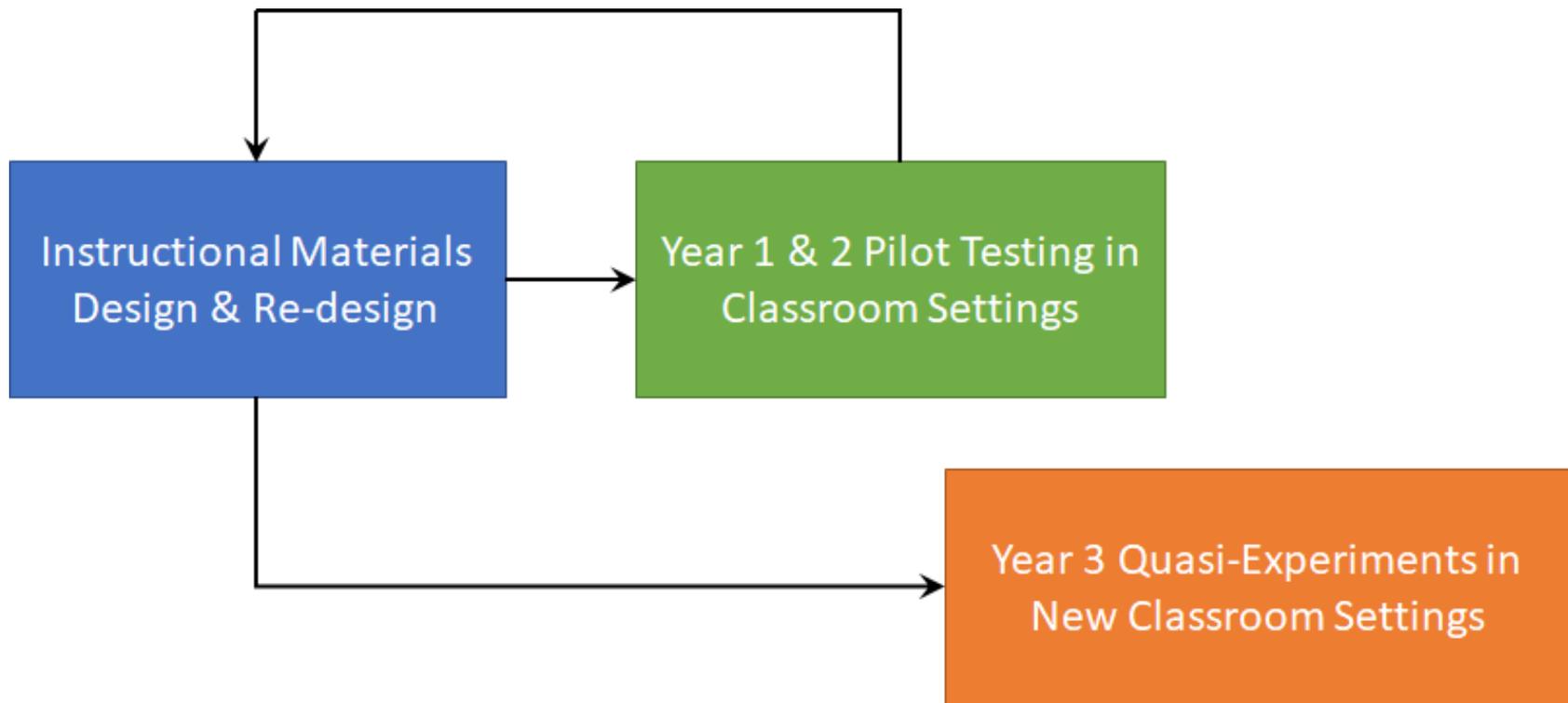


Example of student completed Model-Evidence Link (MEL) diagram

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 water resources & other science topics

Schematic of our first research project (2013-2017)



Our current project examines scaffolds that may increase students' epistemic 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 two of these three models

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

Students who exercise epistemic 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)

The present pilot study 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.

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.

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.

Directions: Write the number of each evidence you are using 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

Evidence #1
Land use changes have prevented large portions of forest, riparian, estuarine, and coastal wetlands from forming. Land changes are affecting both water quality and availability.

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

Evidence #3
Overabundance of fresh water increases the number of people around the world. In many places, people are using groundwater faster than it is recharged by precipitation.

Evidence #4
When wetlands exist, they grow closer to the ground level. They are very dependent on location. Making wetlands available even more difficult.

Evidence #5
Advances in engineering have led to better access to quality drinking water. At the same time, the opportunity and quality of life have improved.

Evidence #6
Estimates of freshwater recharge in a large water body are not able to account for subsurface differences in recharge type or location. This underestimates any effect wetlands might have on water quality.

Evidence #7
Climate is a source of freshwater in many parts of the world. Climate is expected to become increasingly variable.

Evidence #8
Most climate predictions are regional models. Many climate models do not take into account the subsurface differences in recharge type or location. This underestimates any effect wetlands might have on water quality.

Evidence #9
In the contiguous US, average temperature and precipitation have increased since 1910. From 2000-2012, the US has experienced the wettest winter on record in some parts of the country in combination with some 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 = 64 grade 9-12 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.

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.]

| | 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 |

Greatly implausible (or even impossible) Highly Plausible

Case 2: Plausibilistic Reasoning (common)

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 |

Greatly implausible (or even impossible) Highly Plausible

Case 3: Plausibilistic Reasoning (uncommon)

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 |

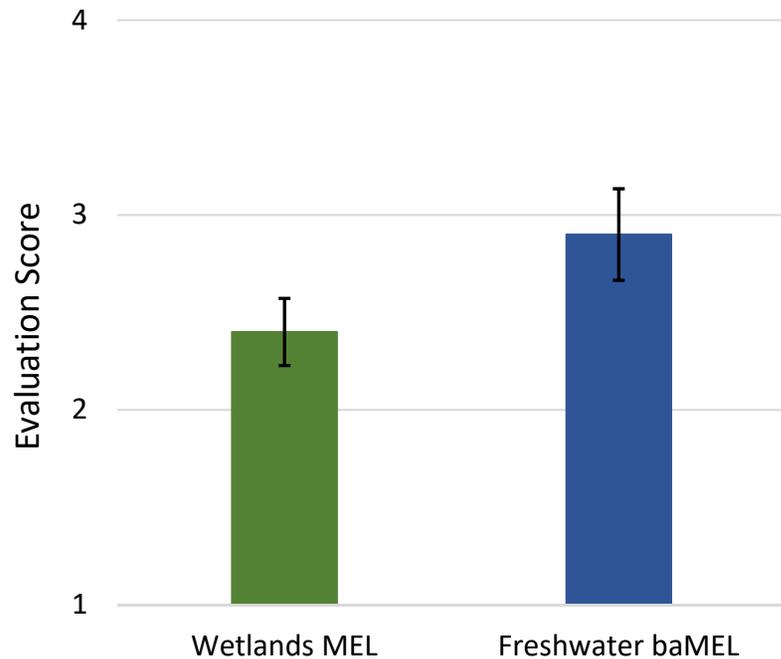
Greatly implausible (or even impossible) Highly Plausible

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

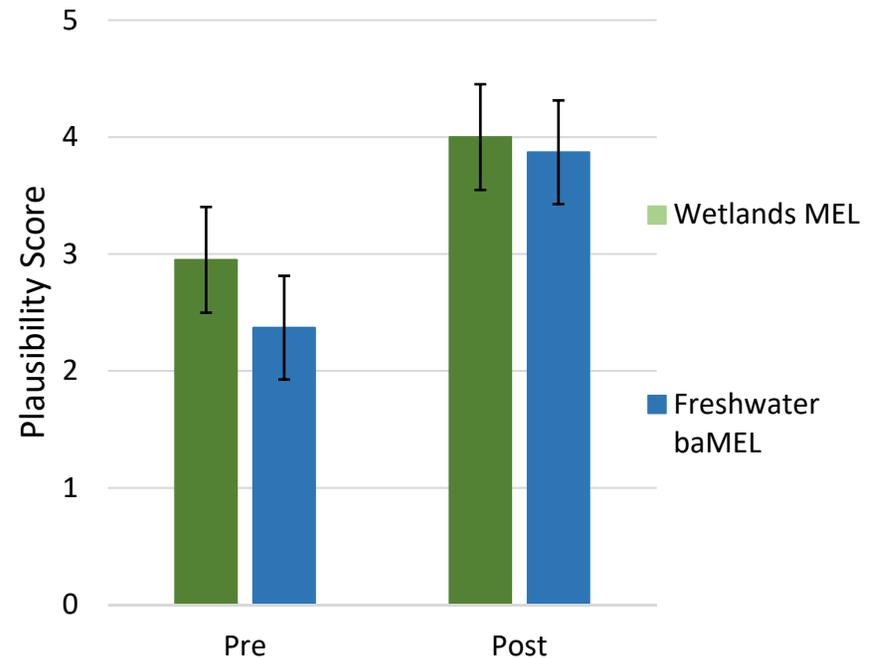
Below are statements about freshwater resources. Rate the degree to which you think that *hydrologists* agree with these statements.

| | 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 <u>surface</u> , <u>but</u> have little impact on the <u>water cycle</u> . | 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 <u>generally uniform</u> . | A | B | C | D | E |
| 7. Global temperatures have increased. <u>But</u> , there has not been an overall <u>decrease in global glacial ice</u> . | 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 <u>been affected by drought in the last 20 years</u> . | 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 |

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

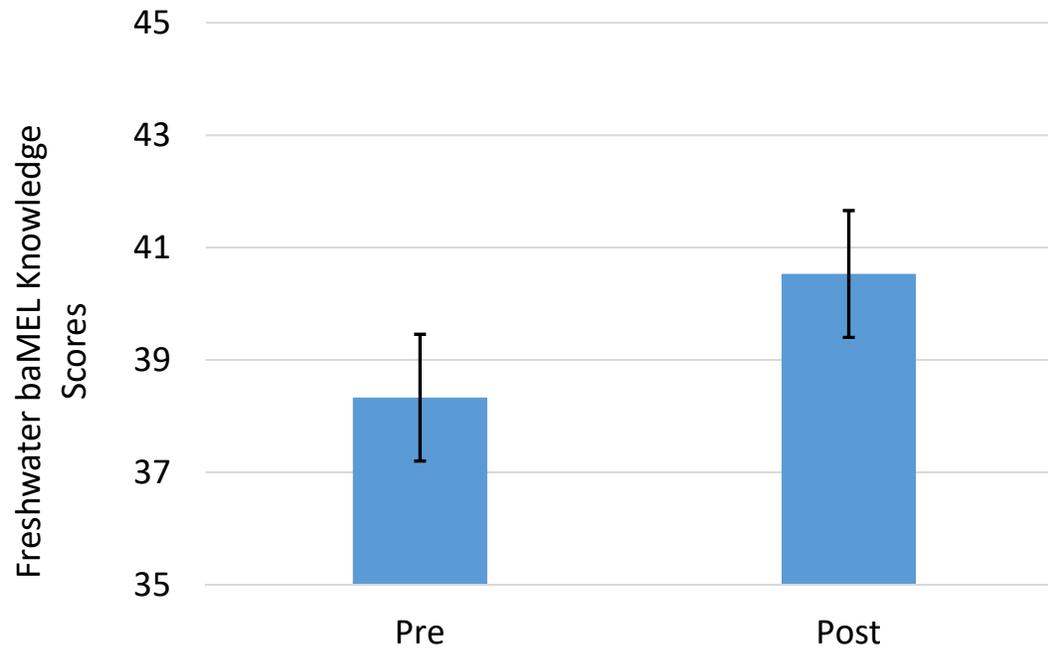


Wilcoxon Signed Ranked Test, $z = 1.17$



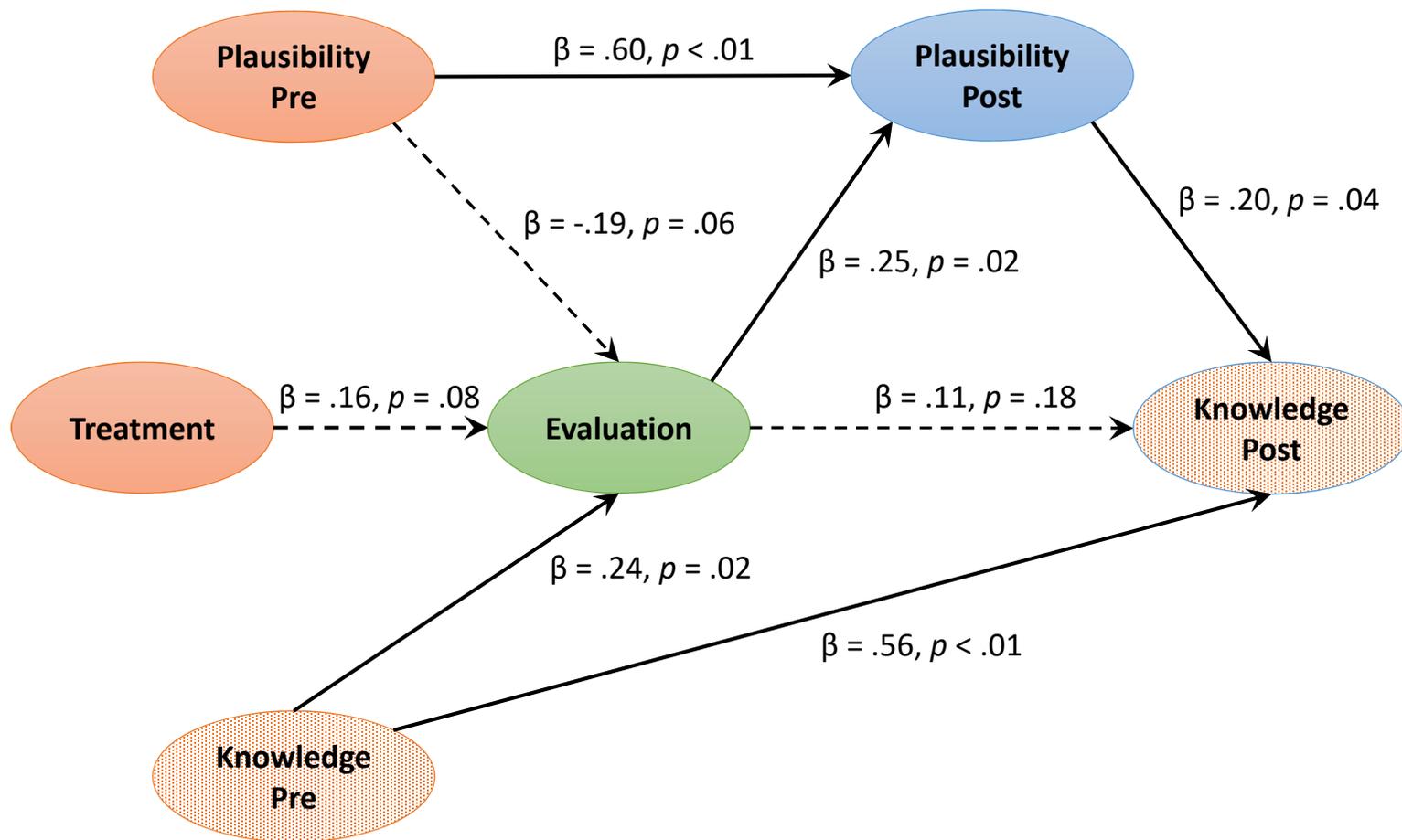
**$z = 2.24$ (Freshwater build-a-MEL)
 $z = 1.88$ (Wetlands pre-constructed MEL)**

The build-a-MEL resulted in somewhat increased knowledge about water resources



Wilcoxon Signed Ranked Test, $z = 1.62$

These pilot data weakly suggest the build-a-MEL may be more effective than the pre-constructed MEL

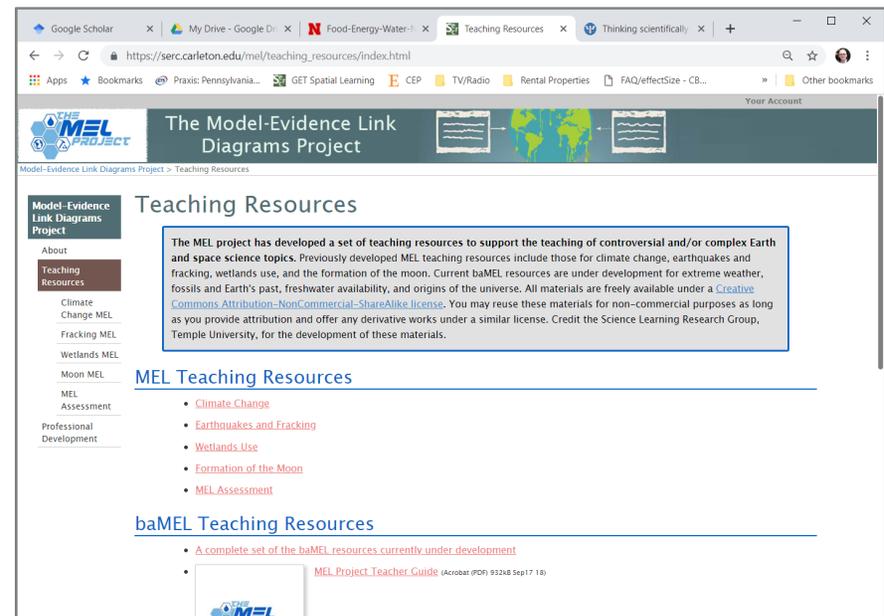


GoF = .562 (large explanatory power), ARS = .316

Currently we are in the midst of Year 2 of our current project



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>

Please consider joining the growing group of educational researchers studying FEW security & sustainability...



..and thanks so much for attending!

A light blue background with a water ripple pattern, featuring a vertical blue line on the left side.

The water challenge:
preserving a global resource

Barclays and the Columbia Water Center explore how energy companies and public utilities can help alleviate water shortages and improve water quality through new technologies and better practices