Teaching Controversial Socio-Scientific Issues: Challenges and Affordances

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The Problem

- Socio-scientific issues (SSIs) are "complex, open-ended, often contentious dilemmas, with no definitive answers" (Sadler, 2004, p. 514)
- Opportunities—but not requirements—exist from national science standards guidance
- Prior research shows using SSIs is valuable, but not widely done

Research Questions

1. Why do teachers choose to teach about SSIs?
2. How do secondary teachers go about incorporating SSI activities into their curriculum?
3. What difficulties do teachers report in engaging students in (a) controversial topics and (b) evidence-based thinking and learning?

Participants and Setting

- Zoom interviews with 18 middle and high school science teachers from mid-Atlantic and Southeastern states
- Participants were part of 2018 or 2019 Summer Institute on connecting scientific models and evidence in Earth/environmental science
  - The MEL Project
- 20-90 minutes each, recorded and transcribed

Analytic Questions

- Why do teachers choose to teach about SSIs and how do they go about it?
- What are the challenges of incorporating SSIs into the curriculum?
- What are the affordances and outcomes of incorporating SSIs into the curriculum?

Coding Process

- Three researchers did an initial pass of subset of transcripts then discussed potential themes
- Divided transcripts among us, with peer debriefing and discussion afterward

Results I: Why teachers teach SSIs

Theme	Example
Help students understand competing ideas in science	Always looking for evidence that contradicts with the theories. So I want to give students an open mind… encourage them to think… present the science, but then what are some arguments against the science that would exist… I think that's really stimulating to the students….so I really like finding evidence, things that contradict theories. (T12)
SSI lessons invite students into real world problems	Talking about climate change and how climate change affects us and how it affects different people's socioeconomic status. (T18)
SSI topics relate to students' lives and build skills for their future	And I want them to know how to be lifelong learners and how to take that approach to different situations when they find a new situation and [are] not sure how to approach it. And then they kind of think, you know, Hmm. And they start applying some of those things without even thinking about that that's what they're applying. That's what I like to see. (T4)
Potential for strong student engagement	[I choose topics that] are things that are generating the most conversations in the classroom with the students and have the highest levels of engagement. And not that it's all about, like, what do you like to do? We're only going to do the things that you like to do, but at the same time, like I want to keep them engaged. (T3)
Effective for practicing NGSS Science and Engineering Practices (SEPs)	It's implementing the, um, science practices….I guess also the engineering practices….evaluating a theory, looking at the evidence and drawing a conclusion.. different ways to, incorporate more of those types of activities with the students. …I feel the students these days, they don't know how to think rationally like a scientist….I think it's all so new to them. They're just used to memorizing things and science. (T12)

Results II: Challenges in teaching science

Theme	Example
Abstract topics difficult for students	Any really abstract concepts teaching about subatomic particles in the atom…origin of the universe, you know, where did the elements come from? Students have difficulty understanding how did like the big bang theory…(T12)
Students struggle with vetting and evaluating evidence	I think a lot of what I struggle with teaching-wise is more scientific literacy than actual content topics. Um, just really getting my students to understand sort of what makes something valid in science and to think scientifically and to recognize… plausibility versus, you know, probability and just kind of understanding data. (T11)
Students struggle with reading overall	Just to make sure that kids are really actually getting information from each one…even simplifying some of them for some of my modified courses…I mean, reading is just a challenge in general. (T11)
Students don't want to talk in class	The more affluent the school [where I've worked] has been… the less willing the students have been to say anything.. It's been more about how do I even get them talking and how to [get] them having meaningful conversation that is both logical and rational. (T3)
Beliefs conflict with science "knowledge"	The attack on information and reliability of information has, especially in the community that I'm in…[students are] like, well, I don't really care what you're telling me because your data is your data. I'll just go find my own. (T3)

Results III: Affordances and Outcomes

Theme	Example
Increase discourse, such as through the evaluation of lines of evidence against competing models	So we all have the same evidence as we all have the same models. They would not come to a consensus, but they all were really, really good at talking about what their different points were and why they felt strongly about doing their project that way. Well, their activity that way. And when I had had that open conversation with them, I felt like, well, this is actually more meaningful than having them all do the same thing. (T14)
Students practice using evidence to make arguments, resulting in deeper thinking	Forcing them to sort of look for evidence and then make a decision based on that evidence rather than just, Oh, well, that's what it says. So it must be true. You know, that's what it says, but does it really support what I've decided here and what I've seen is happening? And it just takes it to that next level of thinking, which a lot of them will just Google it and whatever comes up first is the right answer. You know, they have to come up with their own ideas, they can't just find the answer. And that's always a good thing in this day and age where they can't just rely on a computer to find the information. You have to think about it. So it made them think more. (T8)
Evaluating sources of information on controversial topics	You know, you gotta understand what your point is through evidence….that word model is really talking about a statement or a stance, then you gotta use the evidence to figure out, which one's going to back up the most? And my hope is that what you end up with is in five, 10, 15, 20 years, you have more scientifically literate people on the internet. (T14)

Discussion

- Teachers find using SSIs valuable
  - Students make connections to "real world" and build skills for the future
- SSIs (and MELs) can help students evaluate based on evidence
- SSIs encourage student engagement especially via discourse

Implications for Research

- Teachers need ways to understand students' progress toward using evidence to support arguments and toward overall content understanding
- Scaffolding the process of justification is a critical part of teaching SSIs and what best prepares students for interacting within a democratic society—how to best do this?

Implications for Practice

- Supporting teachers to integrate SSIs is valuable
  - Having a flexible structure helps bring in the topics to existing curriculum
  - Interdisciplinary opportunities
  - Requires differentiation for many groups but still seeing positive outcomes (MEL use)
- Need to do more to bring SSIs into preservice teacher ed *(many of our teachers very experienced but still find training helpful)*

Summary Thoughts from T1

- "…from a content side of things I feel like they were able to come to the conclusions and, and well supported conclusions….I enjoyed how it highlighted scientific thinking deficits and also writing deficits and explaining deficits."

Next Steps

- More detailed analysis of interviews is ongoing
- Manuscript submission goal summer 2021 (*Journal of Science Teacher Education* or *Teaching and Teacher Education*)

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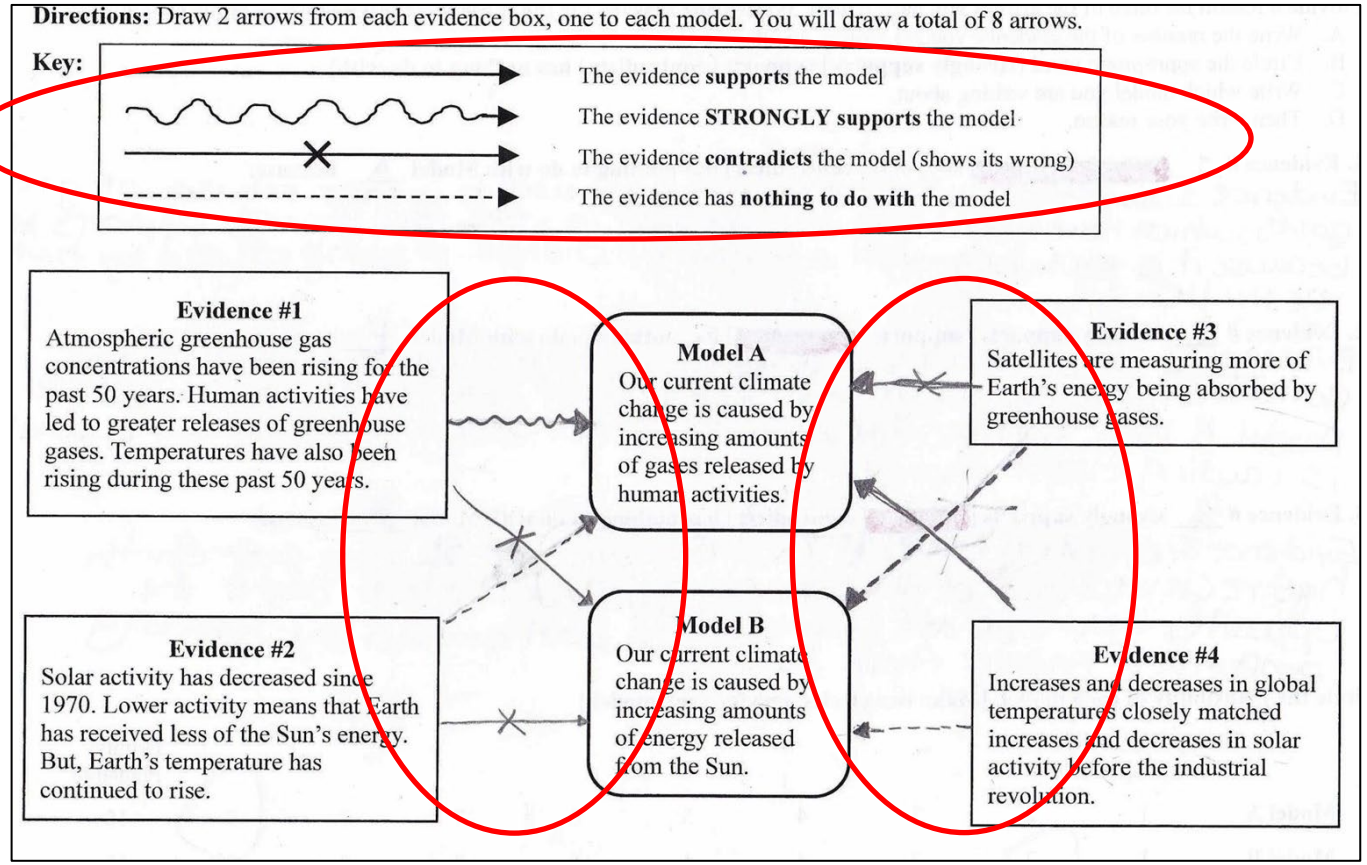
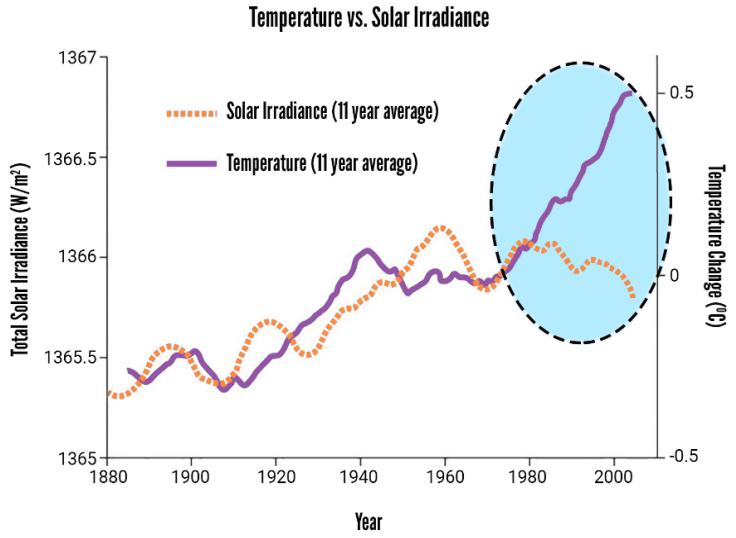
The Model-Evidence Link (MEL) Diagram



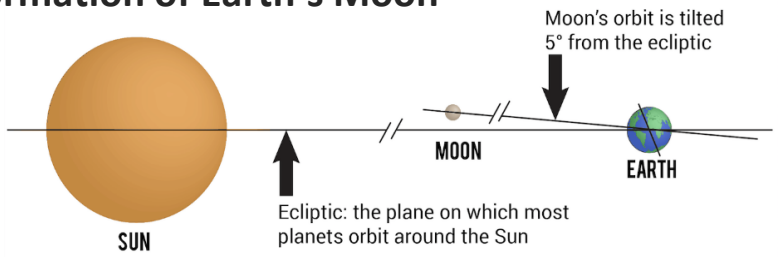
Example of student completed Model-Evidence Link (MEL) diagram

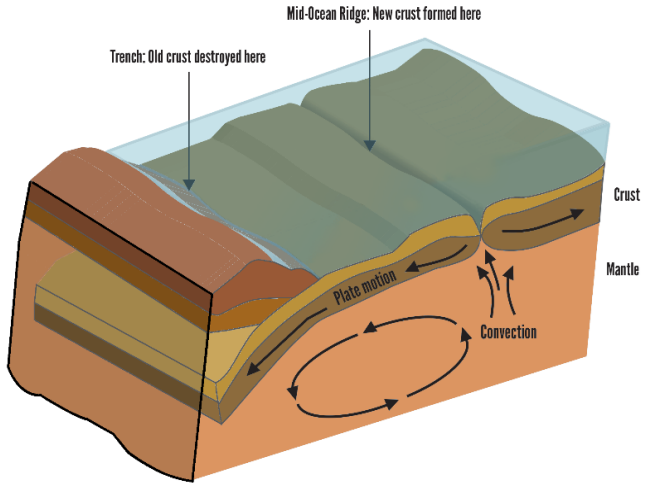
MEL Topics

Causes of current climate change

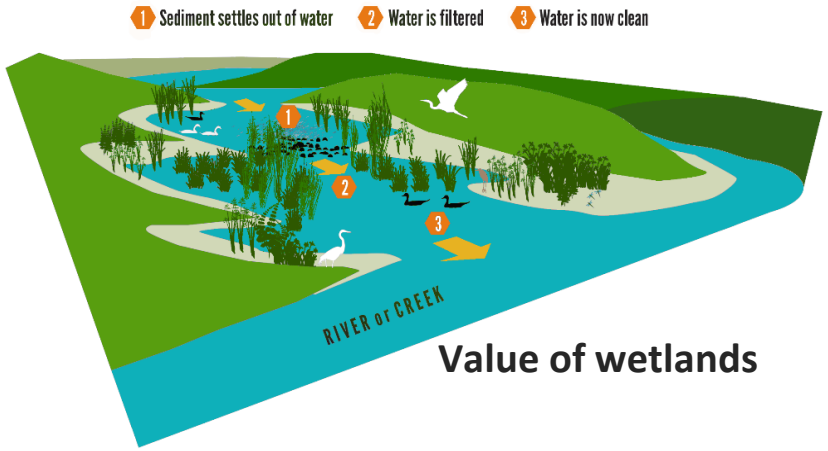


Formation of Earth's Moon





Hydraulic fracturing & earthquakes



Value of wetlands

MEL Step 1: Model Plausibility Ratings

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.

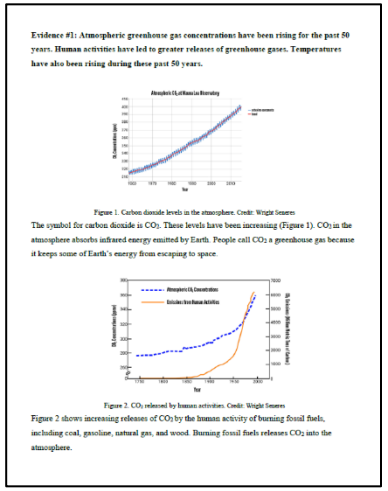
Plausibility is a judgment we make about the potential truthfulness of one model compared to another. The judgment may be tentative (not certain). You do not have to be committed to that decision.

Circle the plausibility of each model. [Make two circles, one for each model.]

	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

Students are introduced to the explanatory models and rate model plausibility

MEL Step 2: Examining the Evidence



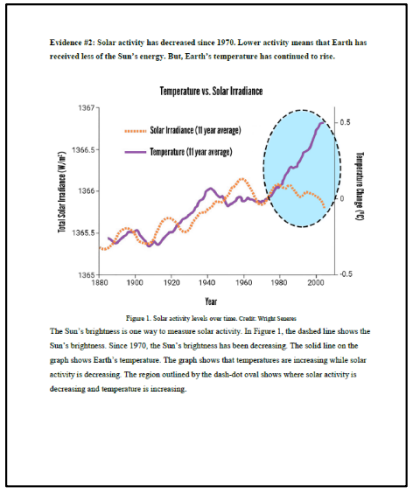
Evidence #1: Atmospheric greenhouse gas concentrations have been rising for the past 50 years. Human activities have led to greater releases of greenhouse gases. Temperatures have also been rising during these past 50 years.

Figure 1. Carbon dioxide levels in the atmosphere. Credit: Wright Senses

The symbol for carbon dioxide is CO_2. These levels have been increasing (Figure 1). CO_2 in the atmosphere absorbs infrared energy emitted by Earth. People call CO_2 a greenhouse gas because it keeps some of Earth's energy from escaping to space.

Figure 2. CO_2 released by human activities. Credit: Wright Senses

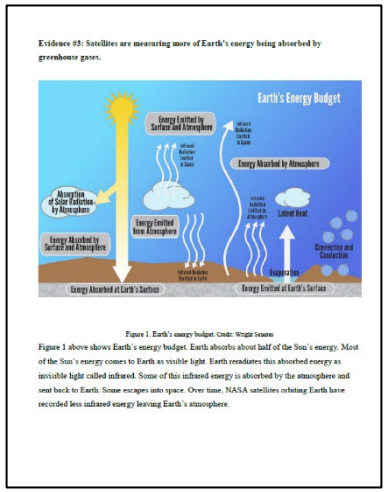
Figure 2 shows increasing releases of CO_2 by the human activity of burning fossil fuels, including coal, gasoline, natural gas, and wood. Burning fossil fuels releases CO_2 into the atmosphere.



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 Senses

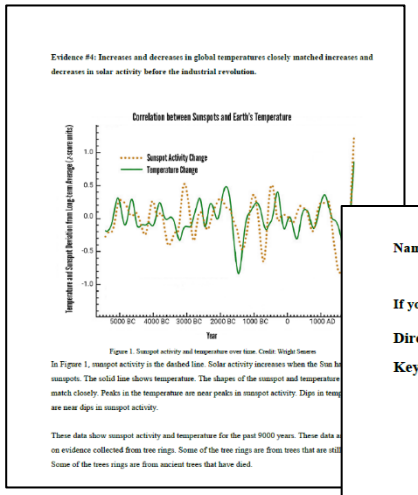
The Sun's brightness is one way to measure solar activity. In Figure 1, the dashed line shows the Sun's brightness. Since 1970, the Sun's brightness has been decreasing. The solid line on the graph shows Earth's temperature. The graph shows that temperatures are increasing while solar activity is decreasing. The region outlined by the dash-dot oval shows where solar activity is decreasing and temperature is increasing.



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

Figure 1. Earth's energy budget. Credit: Wright Senses

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 reradiates 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 #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 Senses

In Figure 1, sunspot activity is the dashed line. Solar activity increases when the Sun has sunspots. The solid line shows temperature. The shapes of the sunspot and temperature match closely. Peaks in the temperature are near peaks in sunspot activity. Dips in temp are near dips in sunspot activity.

These data show sunspot activity and temperature for the past 9000 years. These data a on evidence collected from tree rings. Some of the tree rings are from trees that are still Some of the trees rings are from ancient trees that have died.

Complete the MEL diagram using the evidence texts as a resource

Students work in groups to come to consensus about the arrows to draw

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.

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

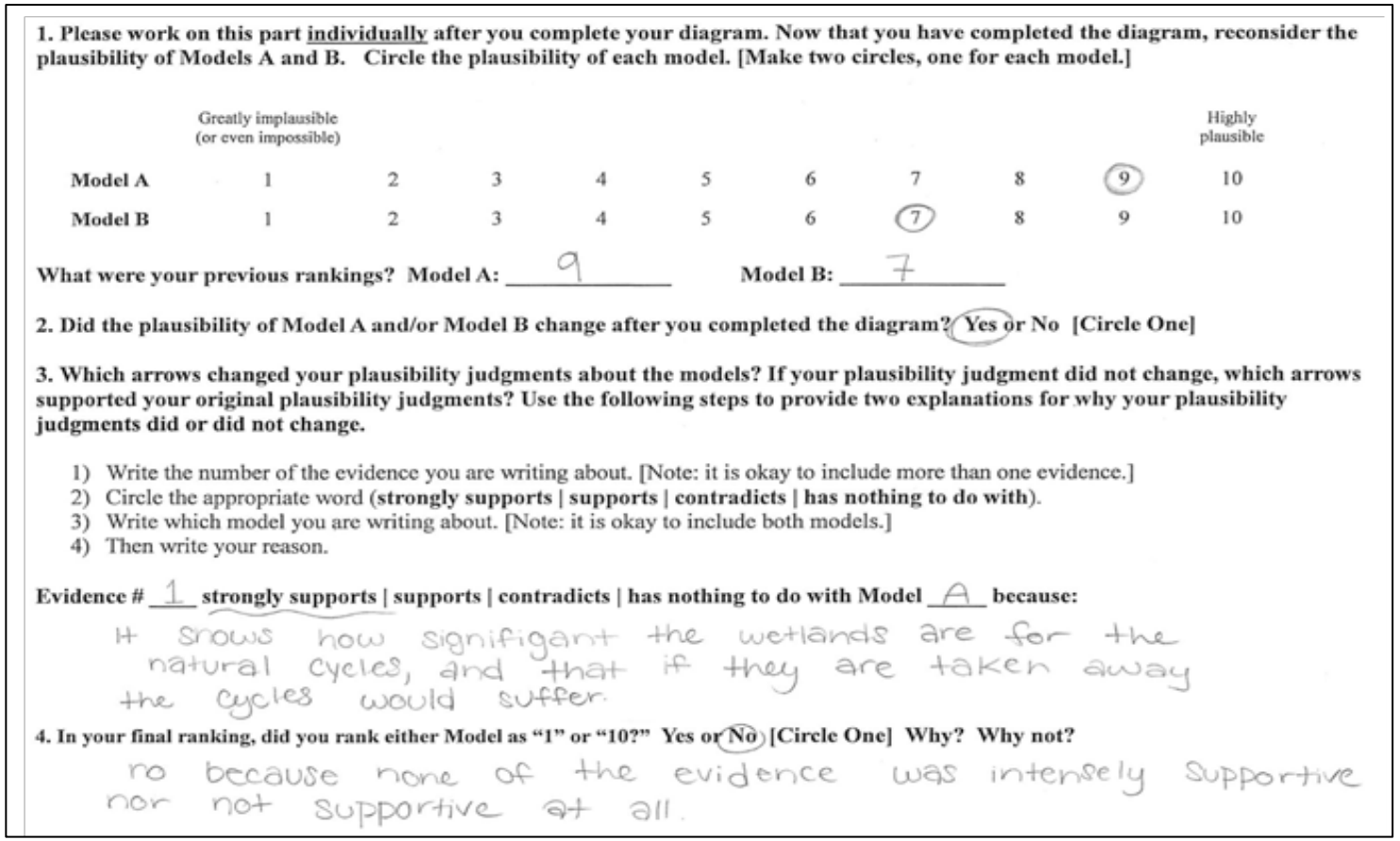
Evidence #3
Satellites are measuring more of Earth's energy being absorbed by greenhouse gases.

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

Evidence #4
Increases and decreases in global temperatures closely matched increases and decreases in solar activity before the industrial revolution.

MEL Step 3: Explanation Task



1. Please work on this part individually after you complete your diagram. Now that you have completed the diagram, reconsider the plausibility of Models A and B. 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

What were your previous rankings? Model A: 9 **Model B:** 7

2. Did the plausibility of Model A and/or Model B change after you completed the diagram? (Yes) or No [Circle One]

3. Which arrows changed your plausibility judgments about the models? If your plausibility judgment did not change, which arrows supported your original plausibility judgments? Use the following steps to provide two explanations for why your plausibility judgments did or did not change.

1) Write the number of the evidence you are writing about. [Note: it is okay to include more than one evidence.]
2) Circle the appropriate word (**strongly supports | supports | contradicts | has nothing to do with**).
3) Write which model you are writing about. [Note: it is okay to include both models.]
4) Then write your reason.

Evidence # 1 **strongly supports | supports | contradicts | has nothing to do with Model** A **because:**

it shows how signifigant the wetlands are for the natural cycles, and that if they are taken away the cycles would suffer.

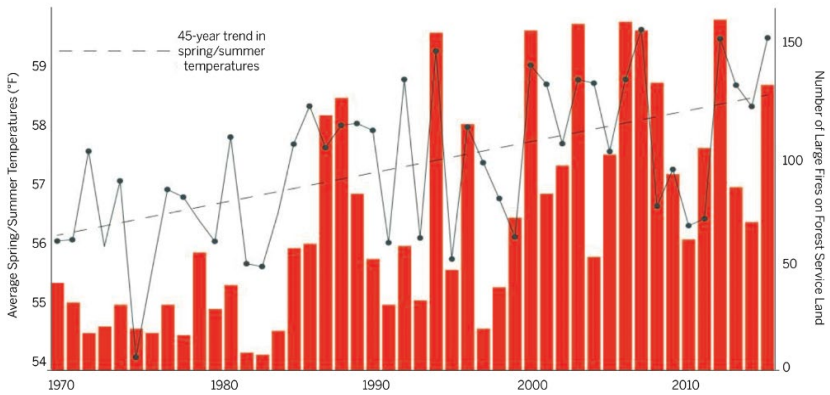
4. In your final ranking, did you rank either Model as "1" or "10?" Yes or (No) [Circle One] Why? Why not?

no because none of the evidence was intensely supportive nor not supportive at all.

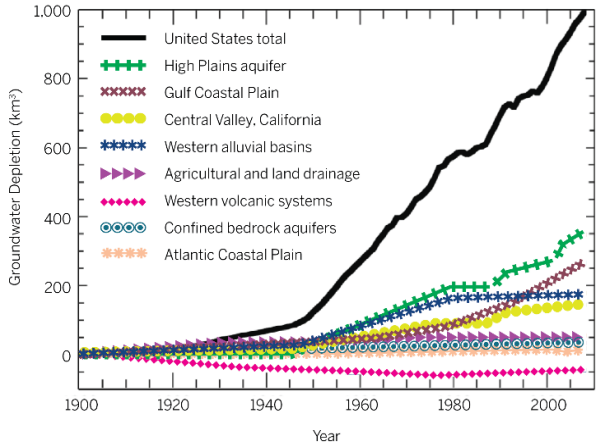
Complete a written explanation task after completing the diagram and then re-rate plausibility of the models

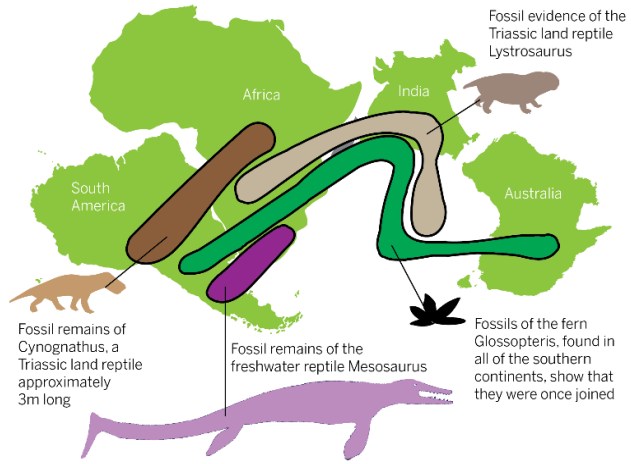
Build-a-MEL Topics

Extreme weather & climate change

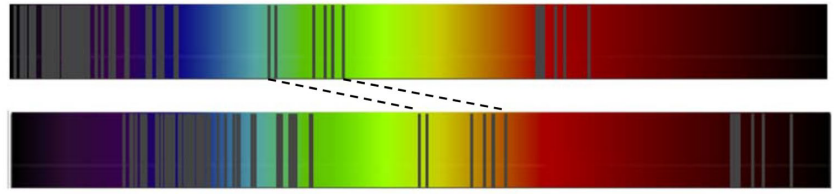


Availability of freshwater resources



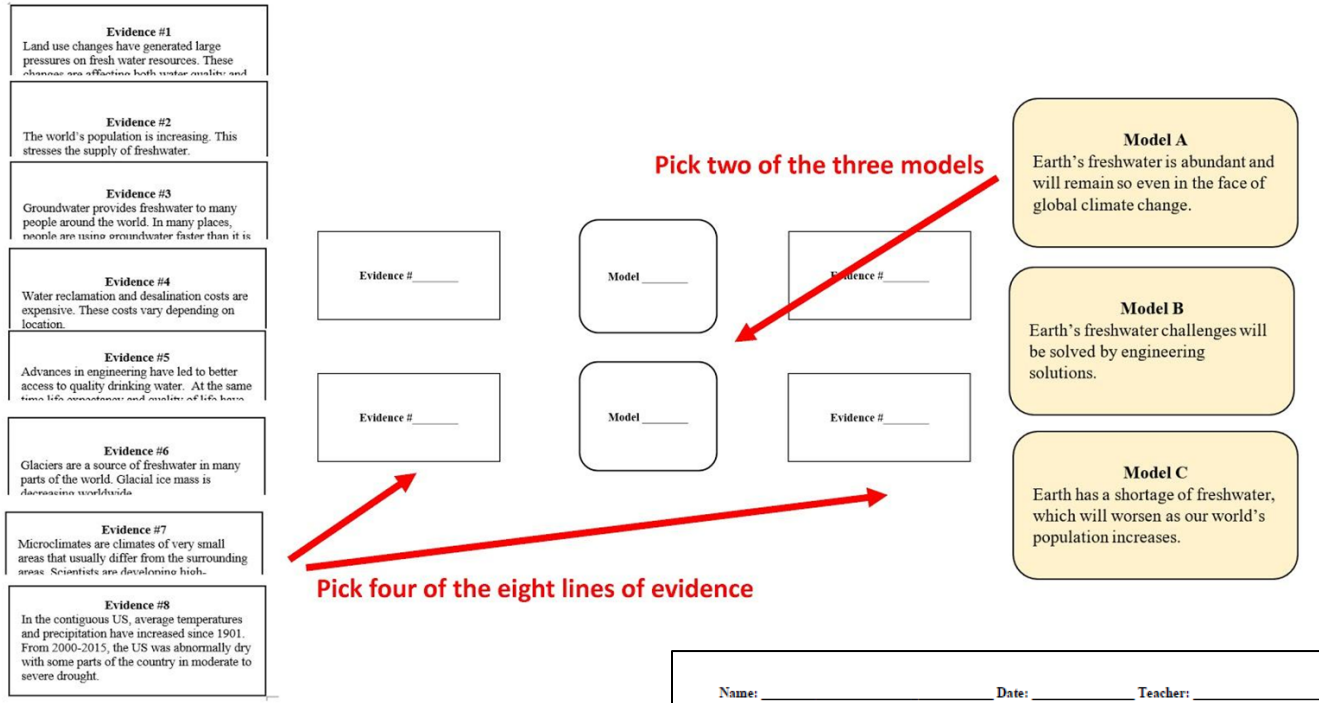


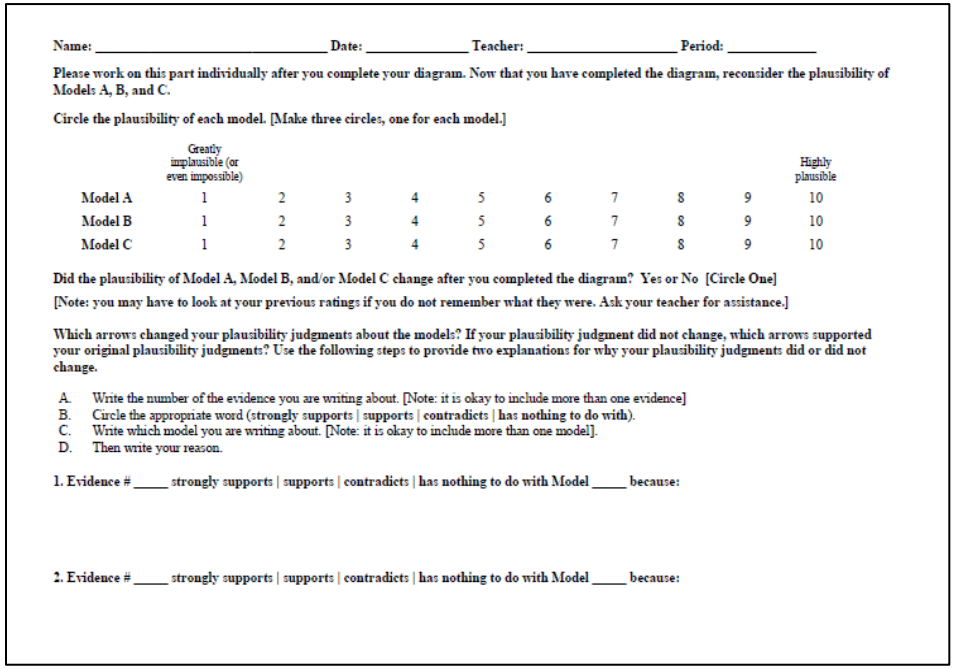
Fossils & Earth's past surface



Origins of the Universe

baMEL: Supporting Students' Agency





Name: _____ Date: _____ Teacher: _____ Period: _____

Please work on this part individually after you complete your diagram. Now that you have completed the diagram, reconsider the plausibility of Models A, B, and C.

Circle the plausibility of each model. [Make three 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
Model C	1	2	3	4	5	6	7	8	9	10

Did the plausibility of Model A, Model B, and/or Model C change after you completed the diagram? Yes or No [Circle One]

[Note: you may have to look at your previous ratings if you do not remember what they were. Ask your teacher for assistance.]

Which arrows changed your plausibility judgments about the models? If your plausibility judgment did not change, which arrows supported your original plausibility judgments? Use the following steps to provide two explanations for why your plausibility judgments did or did not change.

A. Write the number of the evidence you are writing about. [Note: it is okay to include more than one evidence]
B. Circle the appropriate word (**strongly supports | supports | contradicts | has nothing to do with**).
C. Write which model you are writing about. [Note: it is okay to include more than one model].
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: