The MEL Teacher Guide

Implementation and Tips

SCIENCE LEARNING
RESEARCH GROUP

This research project is supported by the US National Science Foundation (NSF) under Grant Nos. 1721041 and 2027376. Any opinions, findings, conclusions, or recommendations expressed are those of the authors and do not necessarily reflect the NSF's views.

Table of Contents

Introduction: Supporting Students' Scientific Thinking with Model–Evidence Link Diagrams

Science classrooms regularly ask students to consider evidence and explanations, and decide what makes sense. In practice, this can be challenging. Students may focus on isolated facts, settle quickly on a single explanation, or struggle to explain *why* certain evidence matters more than other information. The Model–Evidence Link (MEL) diagrams were designed to support students with exactly this kind of thinking.

At their core, MEL diagrams are instructional tools that help students evaluate how lines of evidence relate to competing explanations of a scientific phenomenon. Rather than asking students simply to recall information or choose an answer, MEL activities prompt students to compare alternatives, make judgments, and explain their reasoning. The goal is not for students to fill out a diagram in one correct way, but for them to engage in the kinds of evaluative thinking that scientists use when they weigh how well evidence supports an explanation in light of alternative explanations.

What is a Model–Evidence Link (MEL) diagram?

A MEL diagram is an instructional scaffold designed to help students evaluate how well lines of scientific evidence support an explanation of a phenomenon. Rather than treating evidence as information to be accepted at face value, students use MEL diagrams to make explicit judgments about the strength of the relationship between evidence and an explanatory model.

A key feature of MEL diagrams is that evaluations are made **in relation to alternative explanations**. An evaluation becomes *critical* when students consider not only whether evidence supports a given explanation, but how well it supports that explanation *in light of competing explanations*. This comparative perspective reflects how scientific explanations are evaluated in practice, where evidence gains meaning through contrast with plausible alternatives.

By visually organizing these relationships, the MEL diagram slows students' thinking and supports deliberate consideration of evidence, explanations, and alternatives rather than quick or intuitive conclusions.

MEL diagrams are designed to support three closely related practices:

- **Evaluating evidence in relation to explanations**: Students judge how well specific lines of evidence support, contradict, or are unrelated to an explanation.
- **Engaging in critical evaluation**: Students consider the strength of evidence for one explanation *relative to alternative explanations*, which moves evaluation beyond description to comparison.
- **Explaining evaluative judgments**: Students justify why, in light of the available evidence, one explanation is more plausible (that is, more likely to be truthful) than competing explanations. This judgment focuses on the plausibility of explanations, rather than on the credibility of sources or evidence themselves.

Together, these practices help students develop habits of scientific thinking that emphasize evaluation, comparison, and reasoned judgment.

Why use MEL diagrams?

A growing body of classroom-based research shows that MEL activities can support students' scientific thinking across a range of science topics and grade levels. When students engage repeatedly with MEL diagrams, they tend to become more deliberate in how they evaluate evidence, more willing to consider alternative explanations, and more capable of explaining why certain explanations are more plausible than others.

Importantly, these benefits are not limited to students who already have strong science backgrounds. In research studies, students who initially struggled the most with evaluating evidence often showed substantial growth over time. This suggests that MEL diagrams can serve as a low-cost or free, flexible scaffold that supports diverse learners while keeping the focus on meaningful scientific reasoning rather than rote procedures.

MEL activities are especially well-suited for complex or socially relevant science topics, where students may encounter competing claims and explanations both inside and outside of school. By practicing how to weigh evidence and compare explanations in a structured way, students can develop tools for thinking scientifically beyond a single lesson or topic.

Two ways to use MEL diagrams

This guide includes two main forms of MEL activities: **pre-constructed MELs (pcMELs)** and **build-a-MELs (baMELs)**. Both formats are designed to support the same core thinking practices, but they offer different levels of structure and student choice.

- **Pre-constructed MELs (pcMELs)** provide students with a diagram that already includes a set of explanatory models and lines of evidence. This format offers more structure and can be especially helpful when students are new to evaluating evidence, when the topic is unfamiliar, or when instructional time is limited.
- **Build-a-MELs (baMELs)** ask students to select which models and lines of evidence they will use to construct their own diagram. This format gives students greater agency and encourages deeper comparison and decision-making. It is often useful once students have some experience with MEL activities or when instructional goals emphasize more student autonomy and choice.

Both formats are intended to be flexible instructional tools rather than fixed sequences. Teachers may choose one format or the other based on their students' needs, their learning goals, and the context of their classroom.

Using this guide

The sections that follow provide step-by-step guidance for implementing MEL activities in a variety of settings, including in-person and virtual classrooms. While the guide outlines

recommended practices, teachers are encouraged to adapt the activities to fit their instructional goals and students' experiences. MEL diagrams work best when they are treated as thinking tools that support discussion, reflection, and explanation, not just as worksheets to be completed for their own sake.

By focusing on how students evaluate connections between evidence and explanations, MEL activities aim to support the development of scientific thinking that students can carry with them across topics, courses, and real-world situations.

The MEL Project Teacher Guide

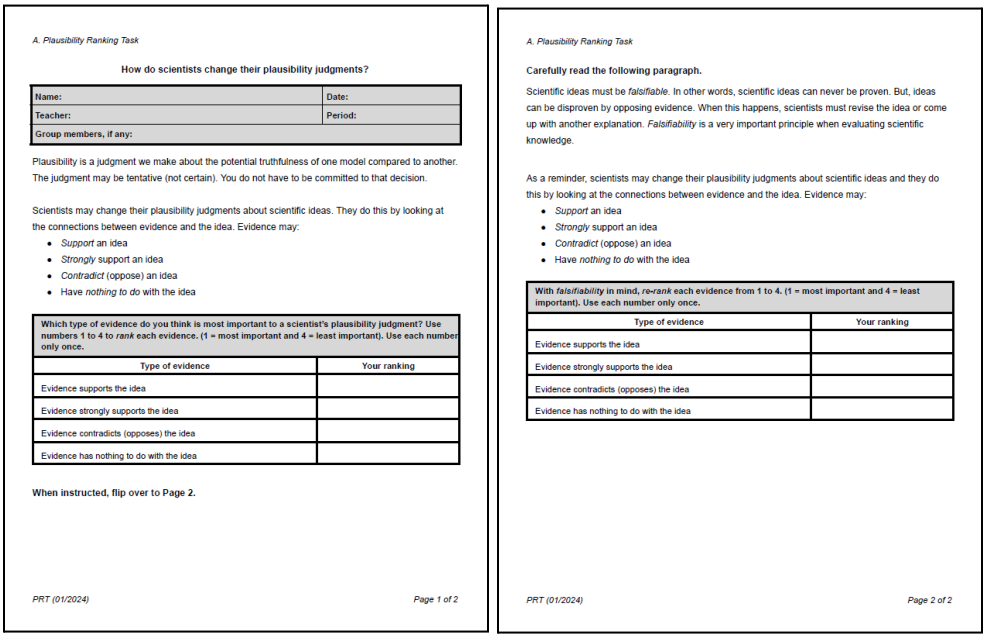
1. MEL Implementation and Tips

SCIENCE LEARNING
RESEARCH GROUP

The pre-constructed (pcMEL) and build-a-MEL (baMEL) activities help students to be critically evaluative to support scientific thinking. Models must be coordinated with lines of evidence to help build an argument about the causes and effects of a particular phenomenon and its systematic relationships. The steps below are a guide to the implementation of both the pcMEL and baMEL activities.

1.1 Complete the ***Plausibility Ranking Task*** (PRT)

This task normally takes about 20 minutes and is only done once or twice at most. If you do multiple pcMELs and baMELs with a given set of students, keep this in mind. This task helps develop understanding about how scientists make judgments about the connection between evidence and models.



A. Plausibility Ranking Task

How do scientists change their plausibility judgments?

Name:	**Date:**
Teacher:	**Period:**
Group members, if any:	

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.

Scientists may change their plausibility judgments about scientific ideas. They do this by looking at the connections between evidence and the idea. Evidence may:

- *Support* an idea
- *Strongly* support an idea
- *Contradict* (oppose) an idea
- Have *nothing to do* with the idea

Which type of evidence do you think is most important to a scientist's plausibility judgment? Use numbers 1 to 4 to *rank* each evidence. (1 = most important and 4 = least important). Use each number only once.

Type of evidence	Your ranking
Evidence supports the idea	
Evidence strongly supports the idea	
Evidence contradicts (opposes) the idea	
Evidence has nothing to do with the idea	

When instructed, flip over to Page 2.

PRT (01/2024) *Page 1 of 2*

A. Plausibility Ranking Task

Carefully read the following paragraph.

Scientific ideas must be *falsifiable*. In other words, scientific ideas can never be proven. But, ideas can be disproven by opposing evidence. When this happens, scientists must revise the idea or come up with another explanation. *Falsifiability* is a very important principle when evaluating scientific knowledge.

As a reminder, scientists may change their plausibility judgments about scientific ideas and they do this by looking at the connections between evidence and the idea. Evidence may:

- *Support* an idea
- *Strongly* support an idea
- *Contradict* (oppose) an idea
- Have *nothing to do* with the idea

With *falsifiability* in mind, *re-rank* each evidence from 1 to 4. (1 = most important and 4 = least important). Use each number only once.

Type of evidence	Your ranking
Evidence supports the idea	
Evidence strongly supports the idea	
Evidence contradicts (opposes) the idea	
Evidence has nothing to do with the idea	

PRT (01/2024) *Page 2 of 2*

Figure 1: Plausibility Ranking Task forms.

a. Students make an initial ranking of the importance of four categories of connections between evidence and models, where a line of evidence:

- strongly supports a model,
- supports a model,
- has nothing to do with a model, or
- contradicts a model.

b. Next, students read the short passage about the tentative nature of scientific information and falsifiability (the ability for a scientific idea to be proven false), as well as the relationship between contradictory evidence and falsifiability.

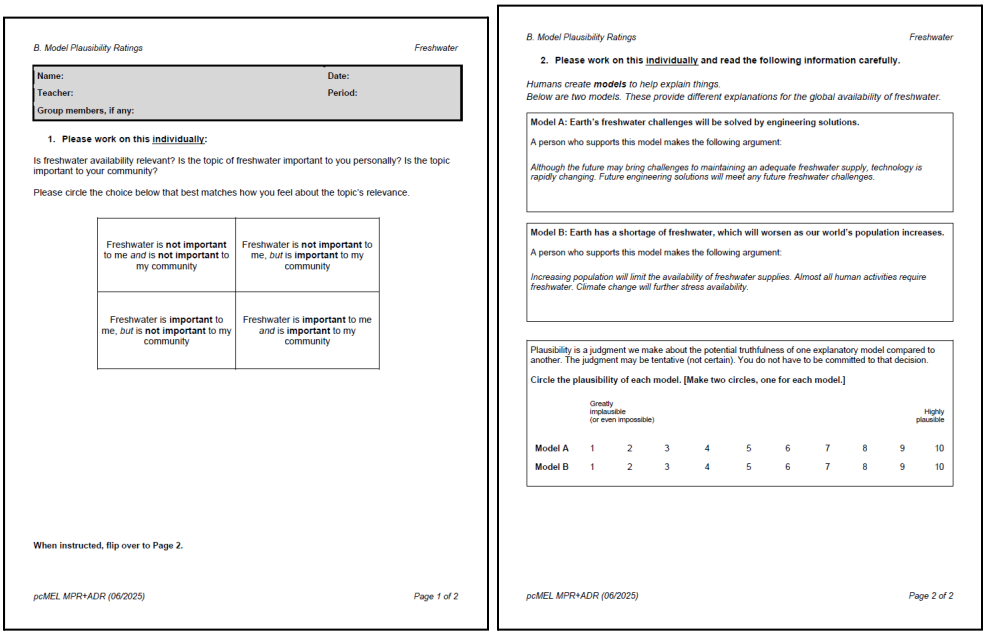
- Conduct a short class discussion on what falsifiability means and why it is important when discussing scientific ideas.

c. Conduct a short, whole-class discussion with the students about the falsifiability passage. Suggested discussion questions:

- How did you rank the categories and why?
- Why do you think [category] is most important?

d. Finally, ask students to re-rank the importance of the categories.

1.2. Rate the plausibility of the two (pcMEL) or three (baMEL) models using the ***Model Plausibility Ratings*** (MPR) handout. Completing this activity takes about 10 minutes and introduces students to the models they will be considering for the MELs (two models for a pcMEL, and three models for a baMEL) and reintroduces students to the idea of plausibility judgments. This should be done as the first activity for each MEL and baMEL.



B. Model Plausibility Ratings *Freshwater*

Name: **Date:**
Teacher: **Period:**
Group members, if any:

1. **Please work on this individually:**

Is freshwater availability relevant? Is the topic of freshwater important to you personally? Is the topic important to your community?

Please circle the choice below that best matches how you feel about the topic's relevance.

Freshwater is **not important** to me *and* is **not important** to my community	Freshwater is **not important** to me, *but* is **important** to my community
Freshwater is **important** to me, *but* is **not important** to my community	Freshwater is **important** to me *and* is **important** to my community

When instructed, flip over to Page 2.

pcMEL MPR+ADR (06/2025) *Page 1 of 2*

B. Model Plausibility Ratings *Freshwater*

2. **Please work on this individually and read the following information carefully.**

*Humans create **models** to help explain things.*
Below are two models. These provide different explanations for the global availability of freshwater.

Model A: Earth's freshwater challenges will be solved by engineering solutions.

A person who supports this model makes the following argument:

Although the future may bring challenges to maintaining an adequate freshwater supply, technology is rapidly changing. Future engineering solutions will meet any future freshwater challenges.

Model B: Earth has a shortage of freshwater, which will worsen as our world's population increases.

A person who supports this model makes the following argument:

Increasing population will limit the availability of freshwater supplies. Almost all human activities require freshwater. Climate change will further stress availability.

Plausibility is a judgment we make about the potential truthfulness of one explanatory 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

pcMEL MPR+ADR (06/2025) *Page 2 of 2*

Figure 2: Model Plausibility Rating task for Freshwater pcMEL.

a. Students individually read about the models.

b. Hold a class discussion to answer questions about the models.

Discussion Tip:
When using the baMEL, consider asking students which model(s) would be good to investigate.

c. Students rate the plausibility of each model. Make sure they draw a circle around one number for each model (there should be two (pcMEL) or three (baMEL) circles).

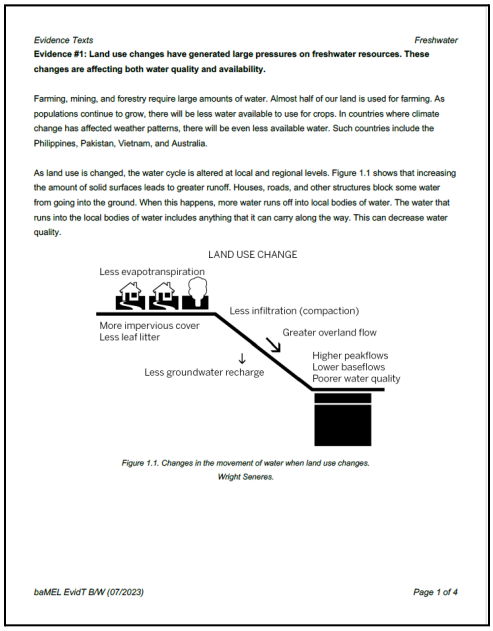
Teaching Tip: Students sometimes feel that the sum of both models should equal 10. For instance, if they rate Model A and "8", they feel Model B is "2". This is especially true for

models that may seem mutually exclusive. It is often a good idea to discourage this by discussing how scientists often hold, prior to testing or seeing evidence, two models as either highly plausible or less plausible prior to examining the evidence or results of a study. It takes a little discipline and maturation to let go of the dichotomous train of thought and withhold judgment -- even just a little as is required by this task -- for many students initially. A useful analogy is how it is best for a judge or jury to try and be open minded about a defendant until they see the cases presented. Further, pointing out how doctors rarely make decisions about care before seeing test results, and often hold several diagnoses as plausible or implausible prior to making observations.

1.3. Read the ***Evidence Texts***. This activity, along with the Model Plausibility Ratings (see above), typically takes about one traditional class period (~50 minutes), although this may vary with your students' experience and reading level.

a. Introduce students to the four Evidence Statements and Evidence Texts for the pcMEL, and eight Evidence Statements and Evidence Texts for the baMEL. Students may be unfamiliar with the types of figures in each evidence text and may need assistance in their interpretation. Consider taking class time to read and discuss each evidence text. This may be accomplished using an instructional routine such as Jigsaw. See the Teaching Tip below for additional guidance on using Jigsaw.

b. Students should read each of the one-page evidence texts.



Evidence Texts *Freshwater*

Evidence #1: Land use changes have generated large pressures on freshwater resources. These changes are affecting both water quality and availability.

Farming, mining, and forestry require large amounts of water. Almost half of our land is used for farming. As populations continue to grow, there will be less water available to use for crops. In countries where climate change has affected weather patterns, there will be even less available water. Such countries include the Philippines, Pakistan, Vietnam, and Australia.

As land use is changed, the water cycle is altered at local and regional levels. Figure 1.1 shows that increasing the amount of solid surfaces leads to greater runoff. Houses, roads, and other structures block some water from going into the ground. When this happens, more water runs off into local bodies of water. The water that runs into the local bodies of water includes anything that it can carry along the way. This can decrease water quality.

Figure 1.1. Changes in the movement of water when land use changes. Wright Seneres.

baMEL EvidT B/W (07/2023) *Page 1 of 4*

Figure 3: Sample Freshwater pcMEL Evidence Text

Teaching Tip: Nearly all evidence texts have unique figures, tables, and graphs. It is a good idea to reiterate what is being shown in the figures, graphs, and tables. Ask students "In your own words, what exactly does Figure 1 tell you about..." to get them thinking. Some students,

when they don't quickly understand the graph or are unfamiliar, will glaze over it. Taking special note of these often becomes useful later in the process as they complete the Explanation Task.

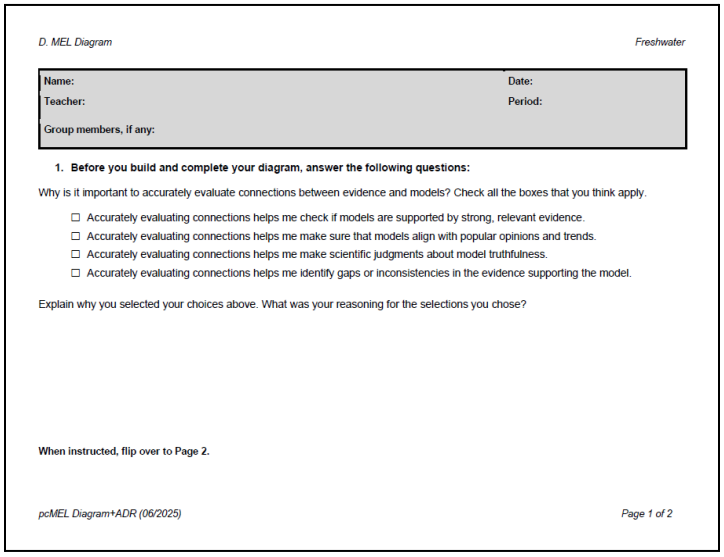
Teaching Tip: It might be useful to introduce two or three evidence texts a day...sort of a "MELs Minutes" format so they do not become overwhelmed with all the evidence. The baMEL format lends itself to considering a format of working on MELs activities for a few minutes a day and reiterating prior evidence each day. It extends the unit to five or six (or more) class periods or more but many students, especially younger ones, benefit from getting this in smaller chunks.

Teaching Tip: You can jigsaw the articles for students to share with one another after they have read all the articles. This ensures all students understand the evidence texts before moving on.

1.4. Students are ready to complete the ***MEL diagram***.

After students have read all the evidence statements and evidence texts, they are ready to complete the MEL diagram following the steps below.

Teaching Tip: If this is the first MEL of the school year, some teachers have students complete a "Group MELs" first feeling it ensures all students will understand the concept of the models and links. They then do their own independent one using their own thinking.



D. MEL Diagram *Freshwater*

Name: **Date:**

Teacher: **Period:**

Group members, if any:

1. **Before you build and complete your diagram, answer the following questions:**

Why is it important to accurately evaluate connections between evidence and models? Check all the boxes that you think apply.

- ☐ Accurately evaluating connections helps me check if models are supported by strong, relevant evidence.
- ☐ Accurately evaluating connections helps me make sure that models align with popular opinions and trends.
- ☐ Accurately evaluating connections helps me make scientific judgments about model truthfulness.
- ☐ Accurately evaluating connections helps me identify gaps or inconsistencies in the evidence supporting the model.

Explain why you selected your choices above. What was your reasoning for the selections you chose?

When instructed, flip over to Page 2.

pcMEL Diagram+ADR (06/2025) *Page 1 of 2*

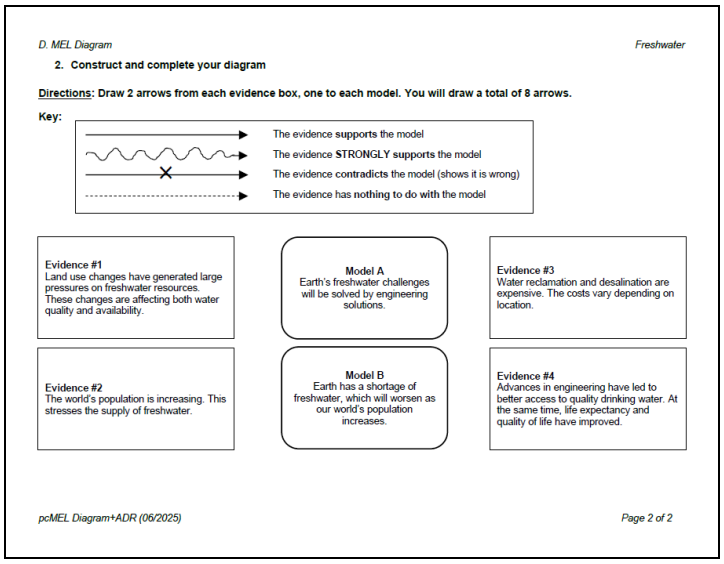


Figure 3: Freshwater pcMEL Diagram

a. Students draw arrows in different shapes to indicate their judgments (which correspond to the four categories in the *Plausibility Ranking Task*) about the strength of the connection between each line of evidence and each model. Each line of evidence should connect to each model (a total of 8 arrows).

- Straight arrows indicate that evidence supports the model
- Squiggly arrows indicate that evidence strongly supports the model
- Straight arrows with an "X" through the middle indicate the evidence contradicts the model
- Dashed arrows indicate the evidence has nothing to do with the model.

Teaching Tip: Ensure all students include eight (8) arrows. It is easy to forget or accidentally leave one link out.

Teaching Tip: Consider laminating the MEL/baMEL diagrams and cards for reuse. By laminating the MEL/baMEL diagrams, students can use water-based markers while they collaborate with their group members. In addition, Laminated cards can be annotated with dry-erase markers by students with language difficulties

b. Students work in teams to discuss the types of connections made between the evidence and models; however, students should be told that if their thoughts lie with an arrow type that's different from their teammates, that they should not change it.

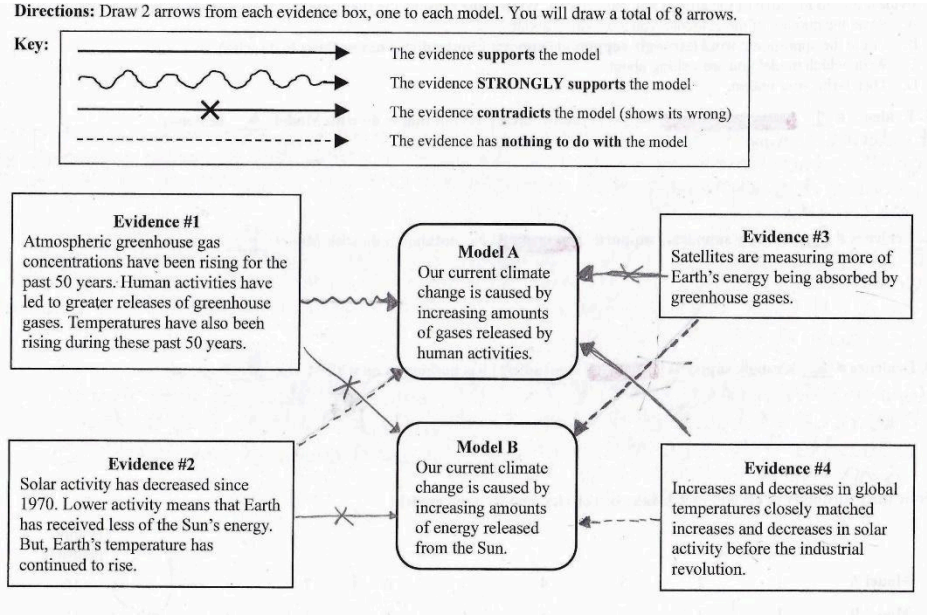


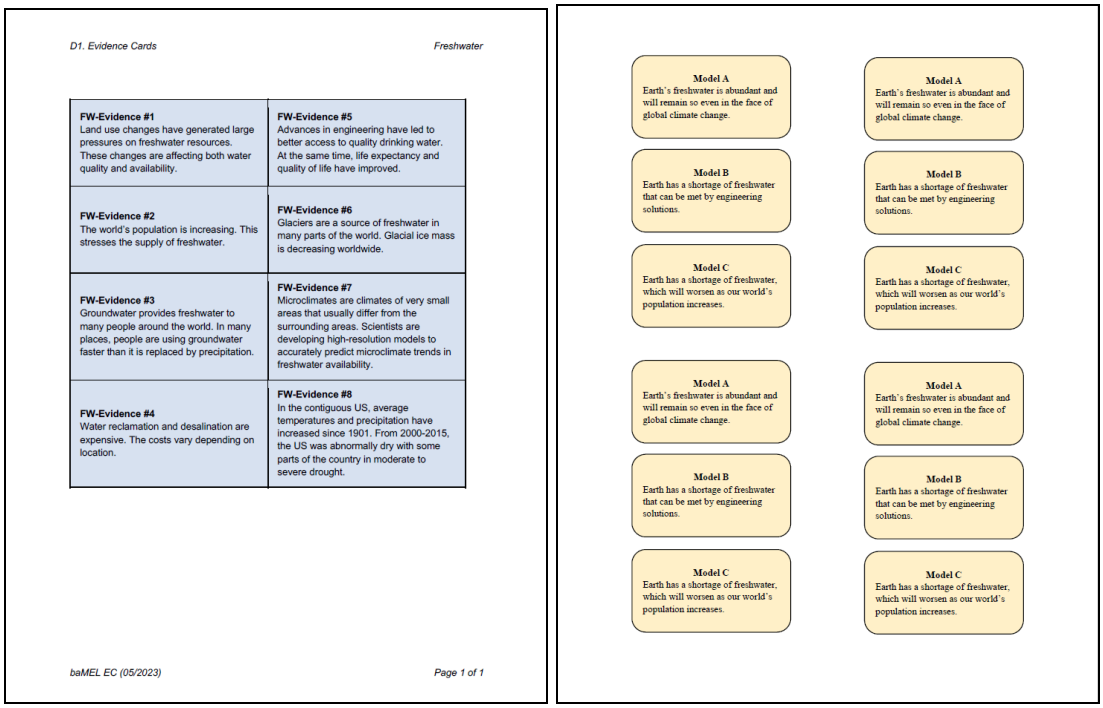
Figure 4: Completed Climate Change pcMEL Diagram

c. Debrief their teamwork and consider constructing a class consensus model while reminding students that their rankings may differ from the class consensus. Note that students may ask which model is scientifically correct. Remind them that they have the pieces of evidence to help them determine which model is scientifically correct.

baMEL Specific Guidance:

Students should have the opportunity to consider and discuss all three models and lines of evidence when making their selections.

a. Give students the 3 model cards and the 8 evidence cards (these should be pre-cut prior to using). Have students lay these out. You may wish to laminate the cards as they are intended for reuse.



D1. Evidence Cards — Freshwater

FW-Evidence #1 Land use changes have generated large pressures on freshwater resources. These changes are affecting both water quality and availability.	**FW-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.
FW-Evidence #2 The world's population is increasing. This stresses the supply of freshwater.	**FW-Evidence #6** Glaciers are a source of freshwater in many parts of the world. Glacial ice mass is decreasing worldwide.
FW-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.	**FW-Evidence #7** Microclimates are climates of very small areas that usually differ from the surrounding areas. Scientists are developing high-resolution models to accurately predict microclimate trends in freshwater availability.
FW-Evidence #4 Water reclamation and desalination are expensive. The costs vary depending on location.	**FW-Evidence #8** 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.

baMEL EC (05/2023) — Page 1 of 1

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.

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.

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.

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.

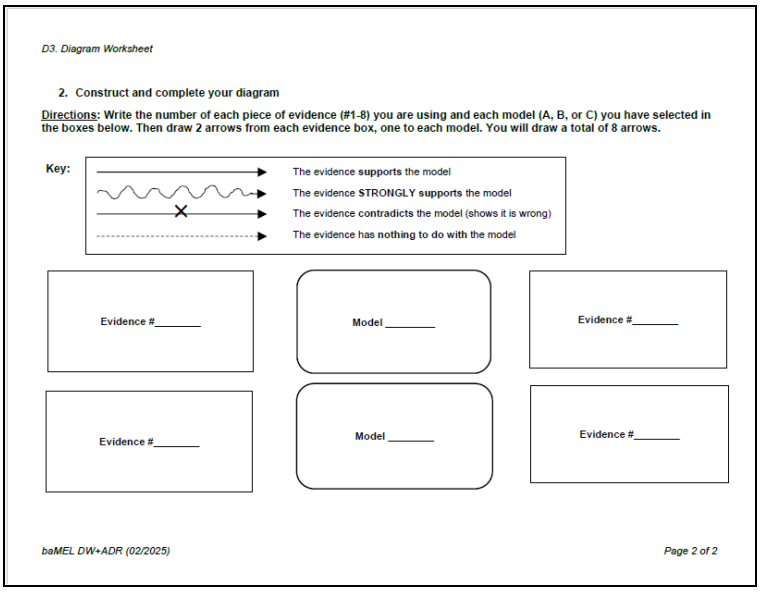
Figure 5: baMEL evidence texts and models cards sheet.

b. Students should select 4 lines of evidence and 2 models from the set from which they will construct a MEL diagram. To help them in their selection of lines of evidence, they should read the one-page evidence texts.

c. Students may need to manipulate the cards and try different combinations in making their decisions about which models and which lines of evidence they will use in their MEL diagrams. Consider allowing students to work in groups of three or four in constructing a baMEL given all the choices they need to consider.

Teaching Tip:
Have the students place unused evidence texts to the side, face down, to make collection easier at the end of the activity.

d. Once students decide their two models and four lines of evidence, they should complete the baMEL worksheet by writing in their selected model letters (A, B, or C) and lines of evidence numbers (1-8). See Figure 7 below.


D3. Diagram Worksheet

2. Construct and complete your diagram

Directions: Write the number of each piece of evidence (#1-8) you are using and each model (A, B, or C) 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 it is wrong)

The evidence has nothing to do with the model

Evidence #_____

Model _____

Evidence #_____

Evidence #_____

Model _____

Evidence #_____

baMEL DW+ADR (02/2025)

Page 2 of 2

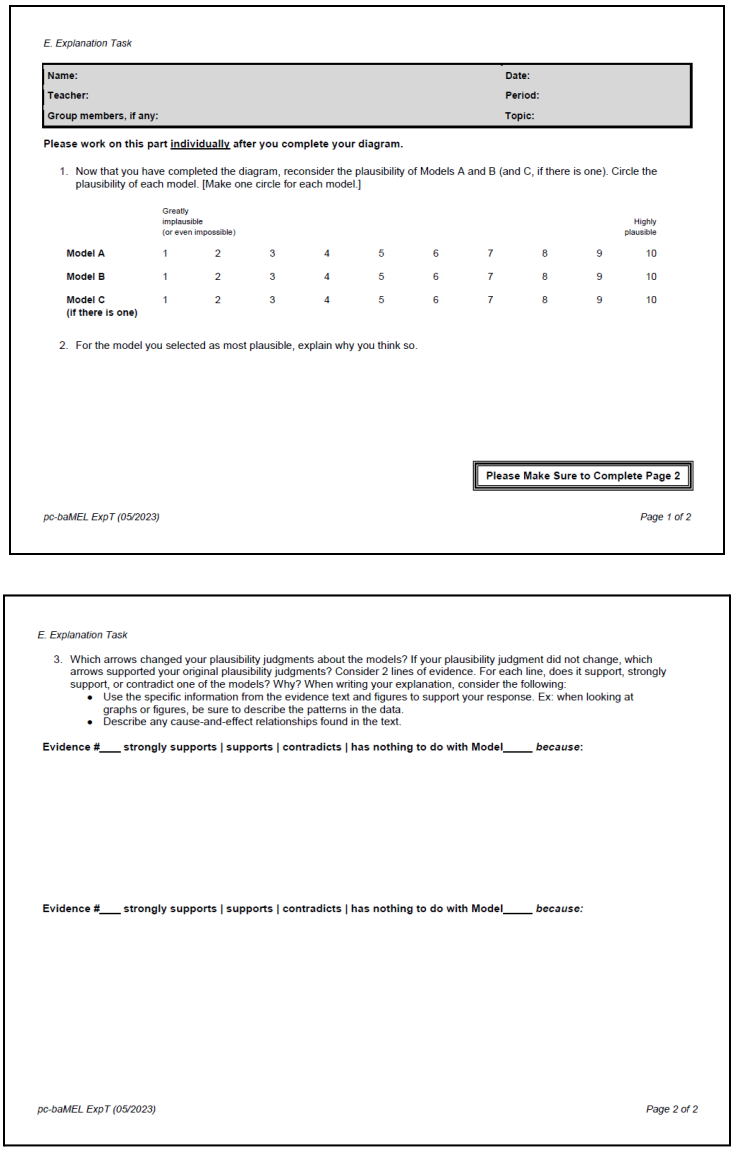
Figure 7: baMEL Diagram - page 2

Teaching Tip:
Have students place models in alphabetical order from top to bottom and the lines of evidence in numerical order from top to bottom/left to right. This will help everyone keep track of their work.

Teaching Tip:
Remind students to fill in their copy of the baMEL digram with a pen or pencil when they are finished! Some students will use the cards only and forget to complete the diagram underneath.

1.5. Students use their completed MEL diagrams in an ***Explanation Task*** (see figure 8 below) to critically evaluate their links and construct understanding. This task asks students to select and write about evidence-to-model links that they made on their MEL diagram.

Teaching Tip:
Students may ask which is the "scientifically correct" model.
Remind them that they have pieces of evidence to help them, from their own ideas about that.



E. Explanation Task

Name:	**Date:**
Teacher:	**Period:**
Group members, if any:	**Topic:**

Please work on this part <u>individually</u> after you complete your diagram.

1. Now that you have completed the diagram, reconsider the plausibility of Models A and B (and C, if there is one). Circle the plausibility of each model. [Make one circle 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 (if there is one)	1	2	3	4	5	6	7	8	9	10

2. For the model you selected as most plausible, explain why you think so.

Please Make Sure to Complete Page 2

pc-baMEL ExpT (05/2023) *Page 1 of 2*

E. Explanation Task

3. Which arrows changed your plausibility judgments about the models? If your plausibility judgment did not change, which arrows supported your original plausibility judgments? Consider 2 lines of evidence. For each line, does it support, strongly support, or contradict one of the models? Why? When writing your explanation, consider the following:
   - Use the specific information from the evidence text and figures to support your response. Ex: when looking at graphs or figures, be sure to describe the patterns in the data.
   - Describe any cause-and-effect relationships found in the text.

Evidence #___ strongly supports | supports | contradicts | has nothing to do with Model_____ *because*:

Evidence #___ strongly supports | supports | contradicts | has nothing to do with Model_____ *because*:

pc-baMEL ExpT (05/2023) *Page 2 of 2*

Figure 8: Explanation Task

a. Students first re-rate the plausibility of each model. These are the same models present in the *Model Plausibility Ratings* and on the MEL diagrams. They also explain why they believe a particular model is the most plausible.

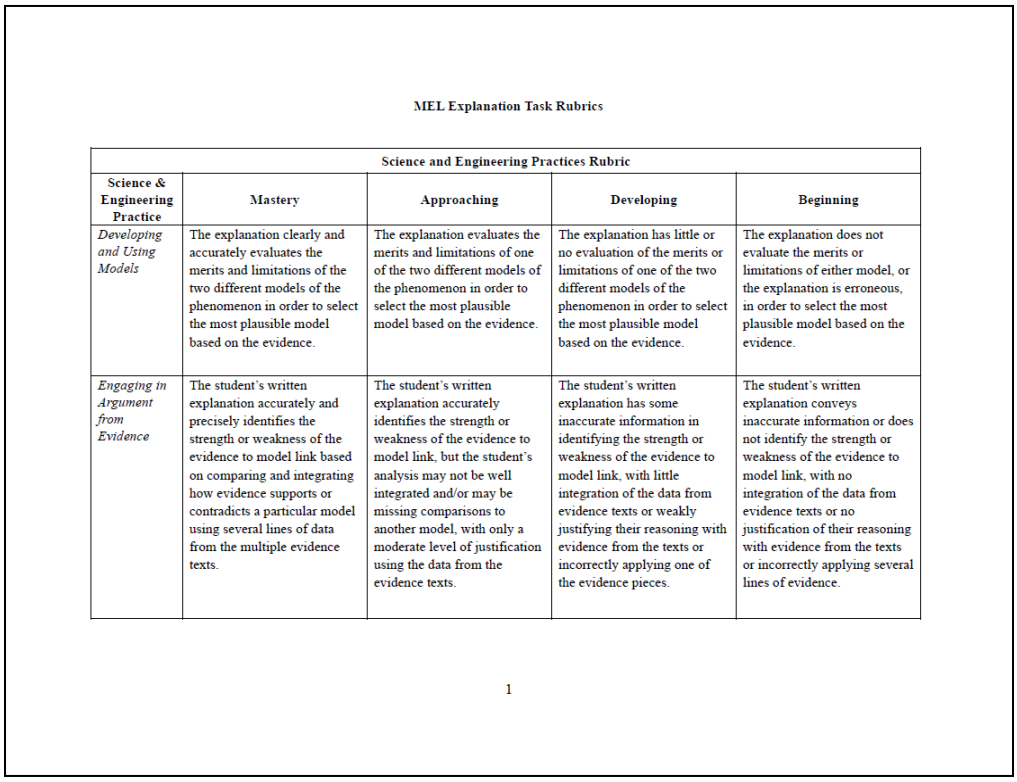
b. In their written explanations (p.2), students select two model-evidence links (arrows), with an evidence statement (which are numbered) at one end and the model (which are lettered) at the other, and elaborate on the relationships. For guidance, tell students they are elaborating on two "arrows."

Teaching Tip: To get the most out of this part of the activity, encourage students to focus on arrows that support, strongly support, or contradict a model. Arrows labeled "have nothing to do with" the model usually do not lead to detailed explanations or meaningful discussion.

Tip: After completing the rating scales it is often helpful to hand back the initial plausibility rating task to better answer question #2. Identifying why (or why not) there were changes in their own ratings is a powerful way to have them reflect on the evidence and even move them forward epistemologically. It also provides them with something they often find easier to write about.

Tip: It is important for students to understand that the two parts to question 3 are actually writing prompts/sentence stems, and they can merely finish the stem. This provides a powerful first sentence in which to elaborate. Many students fail to see it as a stem and start a totally new sentence.

6. Assessing student work. Only the Explanation Task is assessed using the rubric provided. The rubric provides guidance on what to look for related to key Science and Engineering Practices, and/or Crosscutting Concepts.



MEL Explanation Task Rubrics

Science and Engineering Practices Rubric				
Science & Engineering Practice	**Mastery**	**Approaching**	**Developing**	**Beginning**
Developing and Using Models	The explanation clearly and accurately evaluates the merits and limitations of the two different models of the phenomenon in order to select the most plausible model based on the evidence.	The explanation evaluates the merits and limitations of one of the two different models of the phenomenon in order to select the most plausible model based on the evidence.	The explanation has little or no evaluation of the merits or limitations of one of the two different models of the phenomenon in order to select the most plausible model based on the evidence.	The explanation does not evaluate the merits or limitations of either model, or the explanation is erroneous, in order to select the most plausible model based on the evidence.
Engaging in Argument from Evidence	The student's written explanation accurately and precisely identifies the strength or weakness of the evidence to model link based on comparing and integrating how evidence supports or contradicts a particular model using several lines of data from the multiple evidence texts.	The student's written explanation accurately identifies the strength or weakness of the evidence to model link, but the student's analysis may not be well integrated and/or may be missing comparisons to another model, with only a moderate level of justification using the data from the evidence texts.	The student's written explanation has some inaccurate information in identifying the strength or weakness of the evidence to model link, with little integration of the data from evidence texts or weakly justifying their reasoning with evidence from the texts or incorrectly applying one of the evidence pieces.	The student's written explanation conveys inaccurate information or does not identify the strength or weakness of the evidence to model link, with no integration of the data from evidence texts or no justification of their reasoning with evidence from the texts or incorrectly applying several lines of evidence.

1

Figure 9. Explanation Task Rubric - page 1 of 3

The MEL Project Teacher Guide

2. Virtual MEL Implementation and Tips

SCIENCE LEARNING
RESEARCH GROUP

The MEL (pcMEL & baMEL) activities help students to be critically evaluative to support scientific thinking. Models must be coordinated with lines of evidence to help build an argument about the causes and effects of a particular phenomenon and its systematic relationships. This guide will assist in implementing the MEL activities in virtual settings.

2.1. Complete the ***Plausibility Ranking Task*** (PRT)
This task normally takes about 20 minutes and is only done once or twice at most. If you do multiple pcMELs or baMELs with a given set of students, keep this in mind. This task helps develop understanding about how scientists make judgments about the connection between evidence and models.

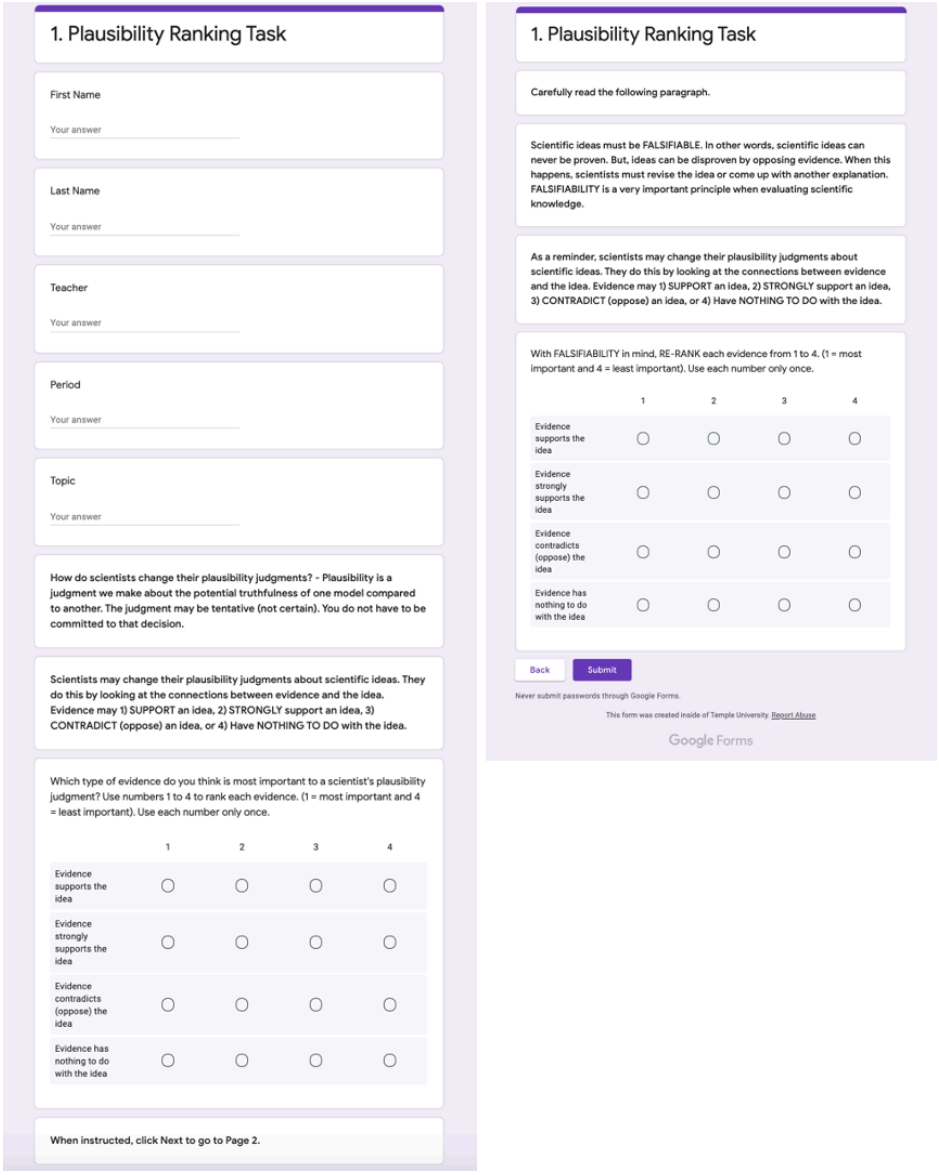


Figure 1: Plausibility Ranking Task Google Form.

a. Students make an initial ranking of the importance of four categories of connections between evidence and models, where a line of evidence

- strongly supports a model,
- supports a model,
- has nothing to do with a model, or
- contradicts a model.

Tip: Note that students should select each number (1-4) only once, so that each connection type has a different rank value.

b. Students read the short passage about the tentative nature of scientific information and falsifiability (the ability for a scientific idea to be proven false), as well as the relationship between contradictory evidence and falsifiability.

- Conduct a short class discussion on what falsifiability means and why it is important when discussing scientific ideas.

c. Conduct a short, whole-class discussion with the students about the falsifiability passage.

d. Students re-rank the importance of the categories and submit their form. Again, note that students should select each number (1-4) only once, so that each connection type has a different rank value.

Discussion Tips:
How did you rank the categories and why?
Why do you think [category] is most important?

2.2. Rate the plausibility of the MEL models using ***Model Plausibility Ratings*** (MPR) Google Form (see Figure 2 below) found in the MEL Google Drive folder for each MEL. Completing this sheet takes about 10 minutes and introduces students to the models they will be considering for the MEL and reintroduces students to the idea of plausibility judgments. This should be done as the first activity for each MEL.

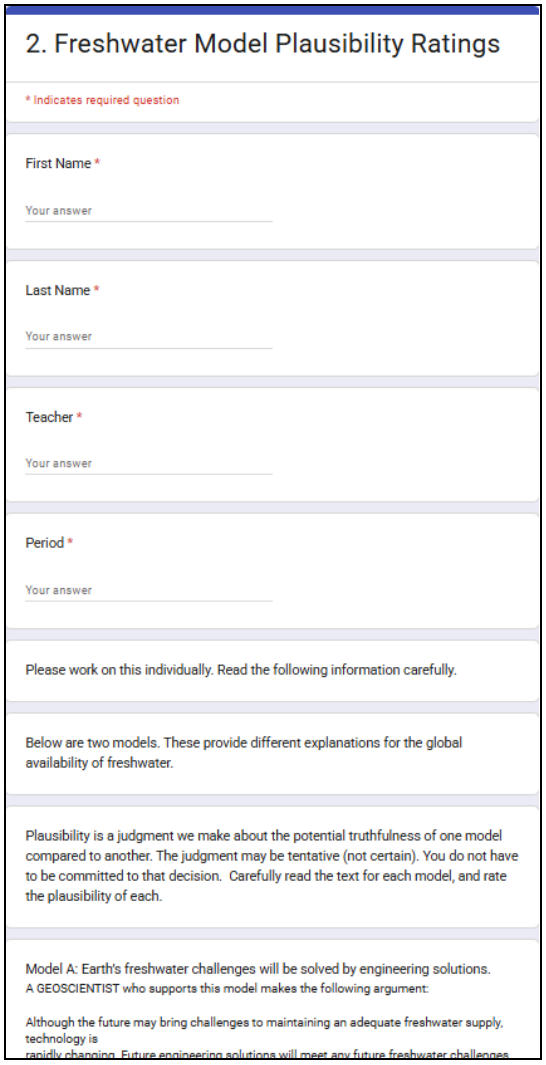


Figure 2: A portion of the Freshwater Model Plausibility Ratings Google Form.

a. Students individually read about the MEL models and plausibility.

b. Hold a class discussion to answer questions about the models and plausibility.

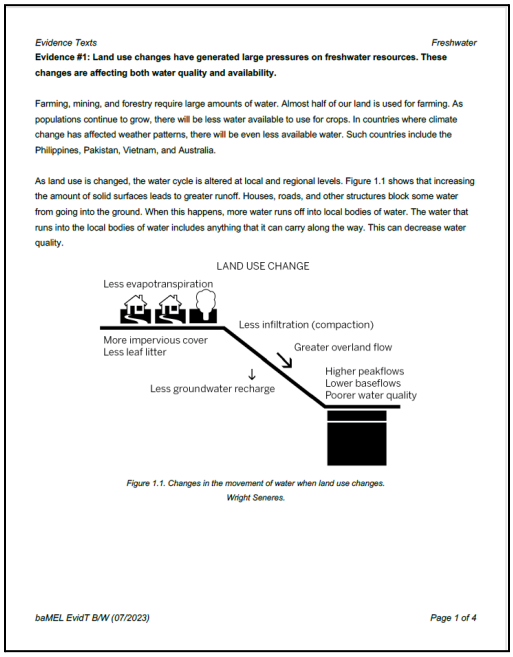
c. Students rate the plausibility of each model; make sure they select one number for each model.

2.3. Introduce students to the four ***Evidence Statements and Evidence Texts*** (found in the Google Drive folder for each pcMEL and baMEL). Students may be unfamiliar with the types of figures in each evidence text and may need assistance in their interpretation. Consider taking class time to read and discuss each evidence text. This may be accomplished using an instructional routine such as Jigsaw.

Teaching Tip: Nearly all evidence texts have unique figures, tables, and graphs. It is a good idea to reiterate what is being shown in the figures, graphs, and tables. Ask students, "In your own words, what exactly does Figure 1 tell you about..." to get them thinking. Some students,

when they don't quickly understand the graph or are unfamiliar, will glaze over it. Taking special note of these often becomes useful later in the process as they complete the Explanation Task.

Teaching Tip: It might be useful to introduce two or three evidence texts a day...sort of a "MELs Minutes" format so they do not become overwhelmed with all the evidence. The baMEL format lends itself to considering a format of working on MELs activities for a few minutes a day and reiterating prior evidence each day. It extends the unit to five or six (or more) class periods or more but many students, especially younger ones, benefit from getting this in smaller chunks.



Evidence Texts *Freshwater*

Evidence #1: Land use changes have generated large pressures on freshwater resources. These changes are affecting both water quality and availability.

Farming, mining, and forestry require large amounts of water. Almost half of our land is used for farming. As populations continue to grow, there will be less water available to use for crops. In countries where climate change has affected weather patterns, there will be even less available water. Such countries include the Philippines, Pakistan, Vietnam, and Australia.

As land use is changed, the water cycle is altered at local and regional levels. Figure 1.1 shows that increasing the amount of solid surfaces leads to greater runoff. Houses, roads, and other structures block some water from going into the ground. When this happens, more water runs off into local bodies of water. The water that runs into the local bodies of water includes anything that it can carry along the way. This can decrease water quality.

Figure 1.1. Changes in the movement of water when land use changes. Wright Seneres.

baMEL EvidT B/W (07/2023) *Page 1 of 4*

Figure 3: pcMEL Freshwater Evidence Statement and Evidence Text.

2.4. Now, students are ready to complete their own ***MEL diagram***. After students have read all the evidence statements and evidence texts, they are ready to select two of the three models to evaluate. Provide students with the MEL Diagram slide deck.

a. Ask students to select two models from slide 3 and place them in slide 4 in the slide deck, and select four evidence statements they will evaluate and also place them in slide 4 in the slide deck.

b. Students complete the MEL diagram following the steps below (the MEL diagram template can be found in the Google Drive folder for each MEL). This will take about one traditional class period (~50 minutes).

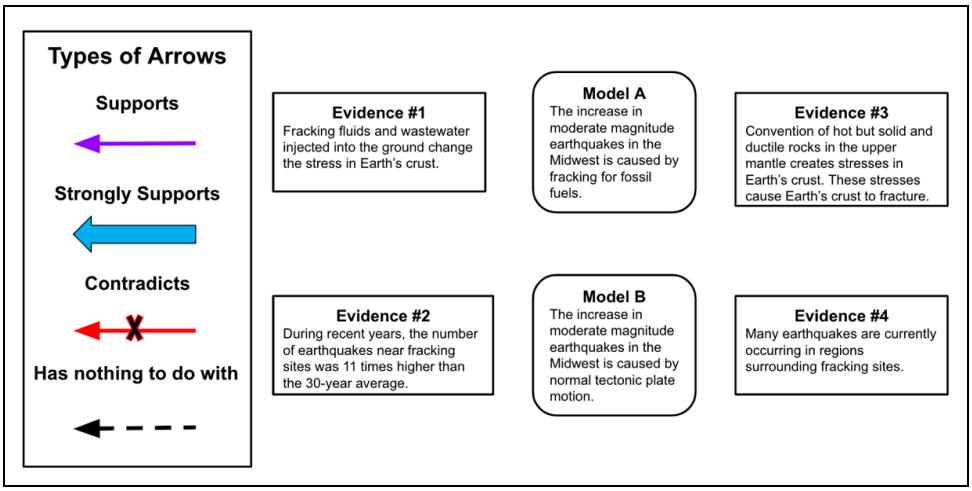


Figure 4: Fracking pcMEL Diagram template.

c. Students select and copy arrows in different shapes to indicate their judgments (which correspond to the four categories in the *Plausibility Ranking Task*) about the strength of the connection between each line of evidence and a model.Each line of evidence should connect to each model (a total of 8 arrows).

- Straight arrows indicate that evidence supports the model
- Squiggly arrows indicate that evidence strongly supports the model
- Straight arrows with an "X" through the middle indicate the evidence contradicts the model
- Dashed arrows indicate the evidence has nothing to do with the model

d. Students work in teams to discuss the types of connections made between the evidence and models, and then create a team model while adding arrows based on their discussions. They should document their discussions using the comment feature. This may occur in a few ways.

- One option is for students to meet synchronously and use the comment feature to add comments on the arrows they are referring to in the diagram as they discuss their choices.

- Another option is for students to work asynchronously and use the comment function to comment on the arrows they are referring to in the diagram.

- With either option, students may use the Chrome Extension called "Mote" which allows students to record short comments on their diagrams. (https://chrome.google.com/webstore/detail/mote-voice-notes-feedback/ajphlblkfpppdpkgokiejbjfohfohhmk?hl=en-US)

Tip: Note that students should not feel compelled to change their arrows on their personal MEL diagram if they are different from what they created with their team.

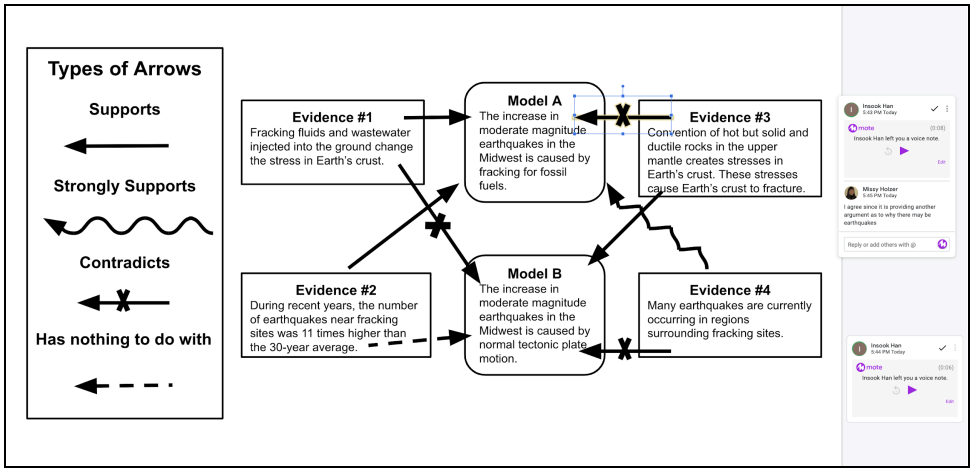


Figure 5: Sample completed Fracking pcMEL Diagram.

Virtual baMEL Specific Guidance:

See Section 1.4 above for baMEL specific implementation guidance. The key difference in the virtual baMEL as compared to the virtual pcMEL is in the slide decks. As above, students will be selecting two of the three models, and four of the eight Evidence Statements and Evidence Texts. However, students will be copying and pasting their selections onto a blank MEL diagram (see Figure 6 below).

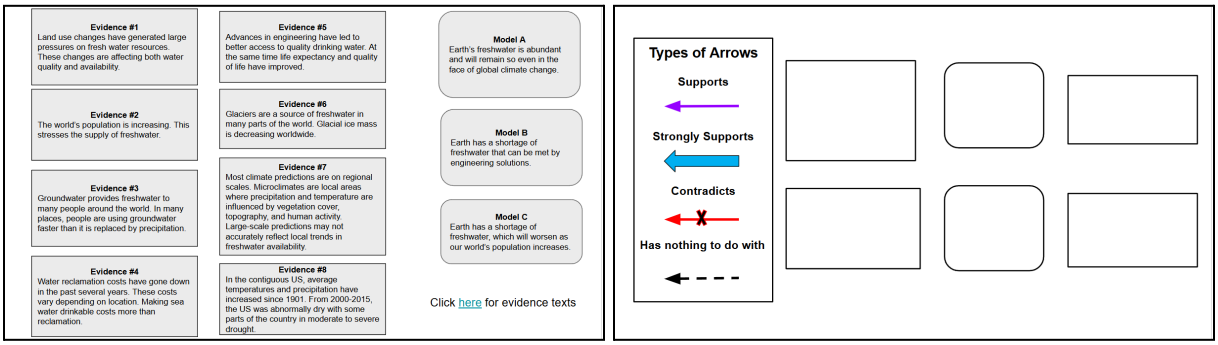


Figure 6: Virtual baMEL slides

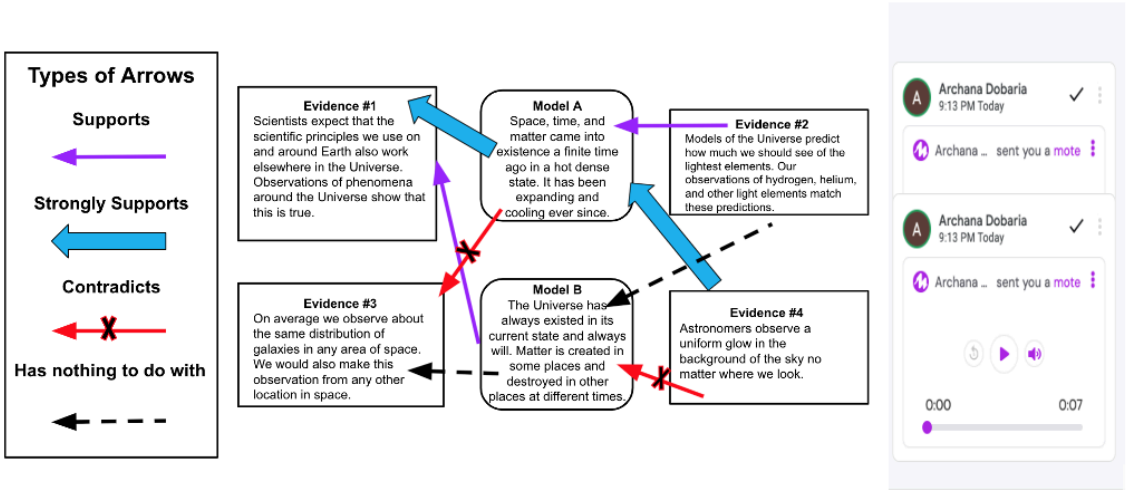


Figure 7: Sample completed Origins of the Universe baMEL Diagram.

2.5. Students next use completed MEL diagrams in an ***Explanation Task*** to critically evaluate their links and construct understanding. This task asks students to select and write about model-evidence links that they had made on their MEL diagram.

Teaching Tip:
Students may ask which is the "scientifically correct" model.
Remind them that they have pieces of evidence to help them, from their own ideas about that.

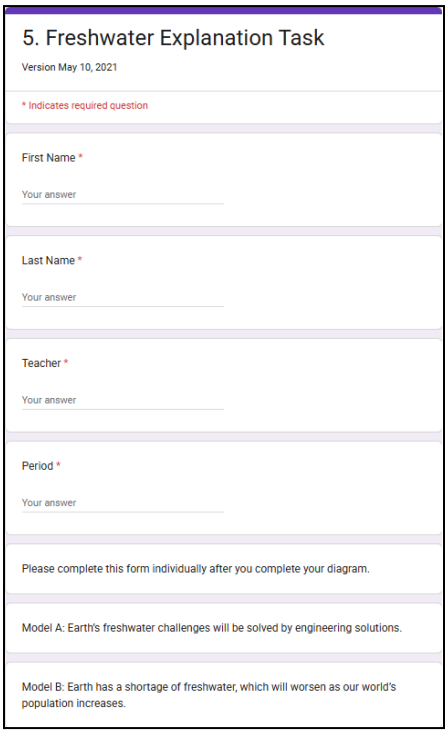


Figure 8: A portion of the Explanation Task Google Form

a. Students first re-rate the plausibility of each model. These are the same models present in the *Model Plausibility Ratings* and on the MEL diagrams. They also explain why they believe a particular model is the most plausible.

b. In their written explanations, students select two model-evidence links (arrows),, with an evidence statement (which are numbered) at one end and the model (which are lettered) at the other, and elaborate on the relationships.

Tip: Identifying why (or why not) there were changes in students' ratings is a powerful way to have them reflect on the evidence and even move them forward epistemologically. It also provides them with something they often find easier to write about.

Teaching Tip: To get the most out of this part of the activity, encourage students to focus on arrows that support, strongly support, or contradict a model. Arrows labeled "have nothing to do with" the model usually do not lead to detailed explanations or meaningful discussion.

6. Assessing student work. Only the Explanation Task is assessed using the rubric provided. The rubric provides guidance on what to look for related to key Science and Engineering Practices, and/or Crosscutting Concepts.

The MEL Project Teacher Guide

3. post-MEL "Science in the News" Activity

SCIENCE LEARNING
RESEARCH GROUP

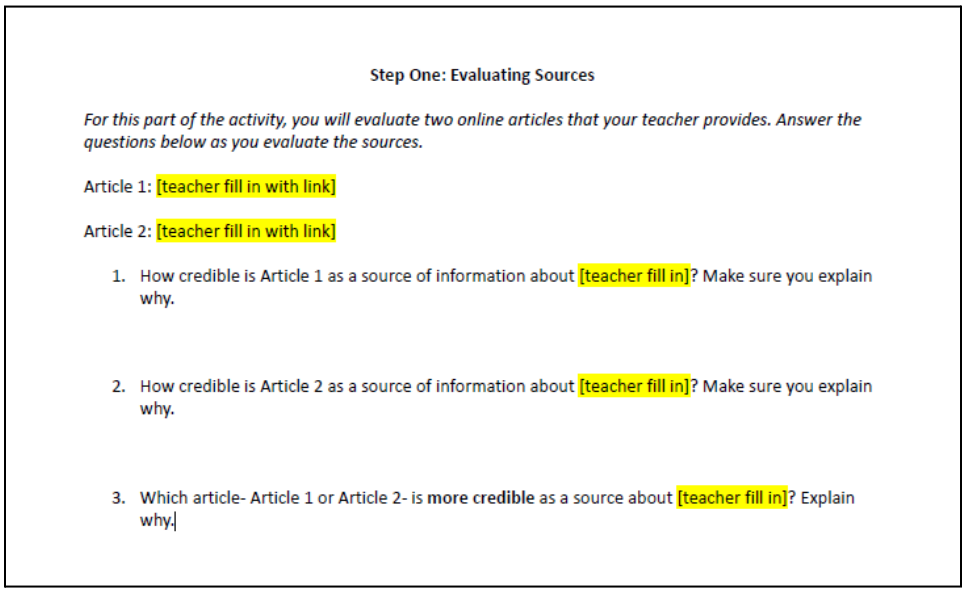
Evaluating Sources, Models, and Evidence in Research Articles

(Note: This activity combines both MEL and Lateral Reading skills.)

Background:
We want students to use lateral reading and the reasoning processes supported by the MEL scaffold in their lives outside the classroom. This flexible transfer task was developed to determine how well students transfer these skills to new situations, such as evaluating sources and claims of articles about science topics.

Students may complete the transfer task in small groups or independently; adjust the steps for implementation below as needed based on your choice. If this is being used as a summative assessment, consider having students work individually.

Steps for Implementation:
1. With students working on laptops or tablets, provide links to two articles on the topic you selected. Students should complete Step One: Evaluating Sources on the graphic organizer.



Step One: Evaluating Sources

For this part of the activity, you will evaluate two online articles that your teacher provides. Answer the questions below as you evaluate the sources.

Article 1: [teacher fill in with link]

Article 2: [teacher fill in with link]

1. How credible is Article 1 as a source of information about [teacher fill in]? Make sure you explain why.

2. How credible is Article 2 as a source of information about [teacher fill in]? Make sure you explain why.

3. Which article- Article 1 or Article 2- is **more credible** as a source about [teacher fill in]? Explain why.

Figure 1: Step 1 of Science in the News Activity

2. The last question on the graphic organizer asks students which article they think is more credible on the topic. Students should complete the next step using only the article they believe is more credible.

Option: At this point, consider taking the time to discuss the credibility judgments students made about each article. Here are a few suggested questions to facilitate that discussion:

- How credible did you decide the first source was, and why? What about the second source?
- Which article do you think is the more credible source of information about this topic? Why?

3. Students read the article they select either by themselves or in small groups using the "low-voice" read-aloud technique. Students are encouraged to mark up the article to highlight important points.

4. Students complete the table in Step 2 and answer Questions 1-3.

Step Two: Evaluating Models and Evaluating Evidence

For this part of the activity, you will first identify the claim or explanatory model presented in a science news article. Then, identify evidence statements that are used to support the model. The number of evidence statements may vary depending on the article you read.

Article Title:	
Claim or Model Presented:	
Evidence #1:	
How does the evidence support the model?	
Evidence #2:	
How does the evidence support the model?	
Evidence #3:	
How does the evidence support the model?	
Is an alternative model presented? If so, what is it? Also provide the evidence supporting it.	

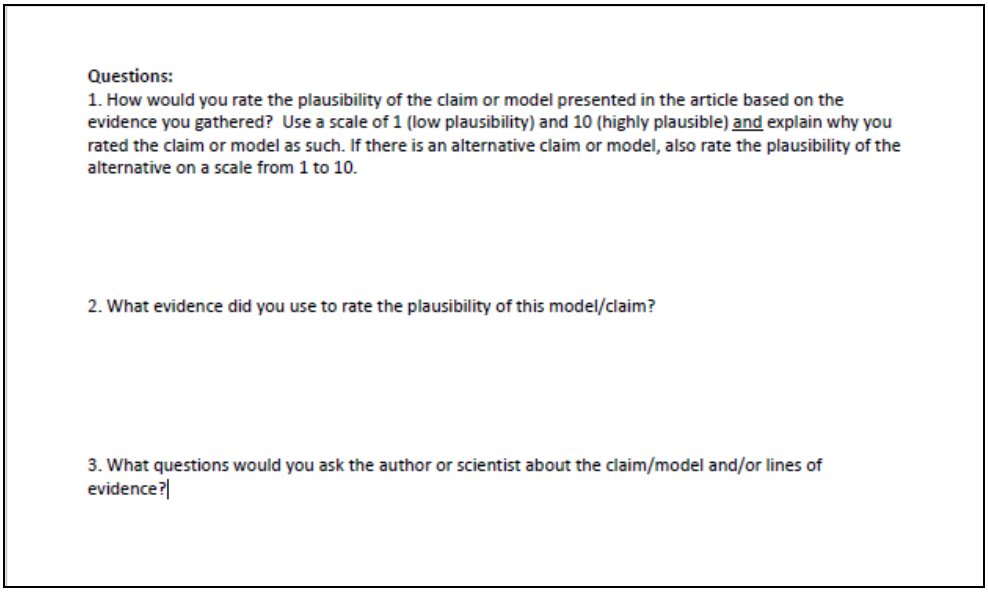


Figure 2: Step 2 of Science in the News Activity

5. Students meet in groups to discuss the article and the contents of their tables. Here are a few prompts:

- How did the evaluation classification (Question 1) vary among your group members?
- What were the key lines of evidence presented?
- How well did each line of evidence support the research individually, and when coupled with the other lines of evidence?

6. Whole Class Discussion: Review students' answers to questions, followed by questions such as these:

- How did your discussion with your group help you learn more about the sources of both articles? Did it change your opinion about the credibility of either article?
- Why did we only ask you to read and analyze the more credible article?
- How did your discussion with your group help your understanding of the content of the article?
- Did you identify additional lines of evidence after your group discussions?
- Were there any alternative models presented in this article? If so, how did you rate them? Why?

Teacher Reflection: Review student work and consider the following questions when assessing their responses.

- How did your students approach evaluating both online articles? Did they show evidence of effectively reading laterally?
- Did most students choose to read the more credible article? How might you further support students who picked the other article?
- What additional support do your students need to improve their skill and efficiency at lateral reading?

- How do your students evaluate models and evidence when presented with evidence? In what ways might you modify this activity to help students think more critically about models and evidence?
- What did students do differently when evaluating articles compared to the MEL task? What similarities?
- What are some of the challenges for students in evaluating evidence?
- How do students consider alternative models in relation to the model at the focus of the article?

Possible Science in the News Articles:

Bundled (MEL & Lateral Reading) Articles:
Articles: some from SN Explores; others from other sites; ideally from sources that students are unfamiliar with (ex: not NYTimes, NatGeo, etc)

Bundle #1 - Measles Cases and Vaccinations
(More credible) https://medicalxpress.com/news/2024-04-global-measles-cases-year.html
(Less credible) https://www.nvic.org/newsletter/feb-2024/measles-truth-consequences

Bundle #2 - GMOs in Food
(More credible)
https://www.nationalacademies.org/based-on-science/foods-made-with-gmos-do-not-pose-special-health-risks
(Less credible)
https://www.corteva.com/resources/blog/plate-wise/are-gmo-foods-safe-article.html

Bundle #3 - Regenerative Agriculture
(Less credible)
https://www.syngentagroup.com/regenerative-agriculture
(More credible)
https://www.weforum.org/agenda/2022/10/what-is-regenerative-agriculture/

Bundle #4 - Nuclear Energy
(more credible)
https://www.weforum.org/agenda/2024/01/nuclear-energy-transistion-climate-change/
(less credible)
https://www.orano.group/en/unpacking-nuclear/7-good-reasons-for-turning-to-nuclear-power-to-combat-global-warming

MEL-only Science in the News Articles:

Here is a list of suggested articles for the transfer task; however, the topics do not necessarily mirror the content of the MELs and baMELs. The criteria used to select these articles included readability level, the research behind the investigations and some of its findings (as opposed to an encyclopedic entry), and the articles being contemporary/engaging. Consider these criteria when seeking your own articles to use for this task. Readabilities were checked with https://www.webfx.com/tools/read-able/

Title: An ancient cold snap causes heated debate: The claim that a comet was responsible just won't die
Date: August 9, 2018
Article focus: Astronomy
Link: https://www.sciencenewsforstudents.org/article/ancient-cold-snap-causes-heated-debate
Readability: Grade 8 (https://www.webpagefx.com/tools/read-able/)

Title: Antarctica's melting speeds up: The continent has lost about 3 trillion metric tons of ice since 1992, raising global sea levels
Date: July 18, 2018
Article focus: Weather and Climate
Link: https://www.sciencenewsforstudents.org/article/antarcticas-melting-speeds
Readability: Grade 7 (https://www.webpagefx.com/tools/read-able/)

Title: Is Zealandia a continent? Landmass lies mostly beneath the Pacific Ocean
Date: March 13, 2017
Article focus: Geology
Link: https://www.sciencenewsforstudents.org/article/zealandia-continent
Readability: Grade 8 (https://www.webpagefx.com/tools/read-able/)

Title: What killed the dinosaurs? New rocky evidence has been emerging about the dinos' final days
Date: January 30, 2017
Article focus: Fossils with Animals, Earth Science
Link:
https://www.sciencenewsforstudents.org/article/dinosaurs-extinction-asteroid-eruptions-doom
Readability: Grade 9 (https://www.webpagefx.com/tools/read-able/)

Title: Oxygen-rich air emerged super early, new data show: If correct, it occurred before the evolution of animal life
Date: August 21, 2016
Article focus: Earth Science with Chemistry, Evolution
Link:https://www.sciencenewsforstudents.org/article/oxygen-rich-air-emerged-super-early-new-data-show
Readability: Grade 7 (https://www.webpagefx.com/tools/read-able/)

Title: Western U.S. on the rise: Ongoing drought-induced uplift in the western United States
Date: September 26, 2014 (AAAS Science article date)
Article focus: Water use
Link: https://www.scienceintheclassroom.org/research-papers/western-us-rise
Readability: Grade 8 (https://www.webpagefx.com/tools/read-able/)

Title: Distant galaxy seems filled with dark matter
Date: September 21, 2018
Article focus: Astronomy, physics, deep space
Link: https://www.sciencenewsforstudents.org/article/distant-galaxy-seems-filled-dark-matter
Readability: Grade 8 (https://www.webpagefx.com/tools/read-able/check.php)

Title: New tools aim to better predict blooms of toxic algae
Date: September 19, 2018
Article focus: Oceans, ecosystems
Link:
https://www.sciencenewsforstudents.org/article/new-tools-aim-better-predict-blooms-toxic-algae
Readability: Grade 8 (https://www.webpagefx.com/tools/read-able/check.php)

Title: Ocean heat waves are on the rise - and killing coral
Date: May 18, 2018
Article focus: Oceans, climate, animals
Link:
https://www.sciencenewsforstudents.org/article/ocean-heat-waves-are-rise-and-killing-coral
Readability: Grade 7 (https://www.webpagefx.com/tools/read-able/)

Title: Water waves can have literally seismic impacts
Date: January 12, 2018
Article focus: Earth, geology, physics
Link:
https://www.sciencenewsforstudents.org/article/water-waves-can-have-literally-seismic-impacts
Readability: Grade 7 (https://www.webpagefx.com/tools/read-able/)