The MEL Project Teacher Guide

Directions and Hints

SCIENCE LEARNING RESEARCH GROUP

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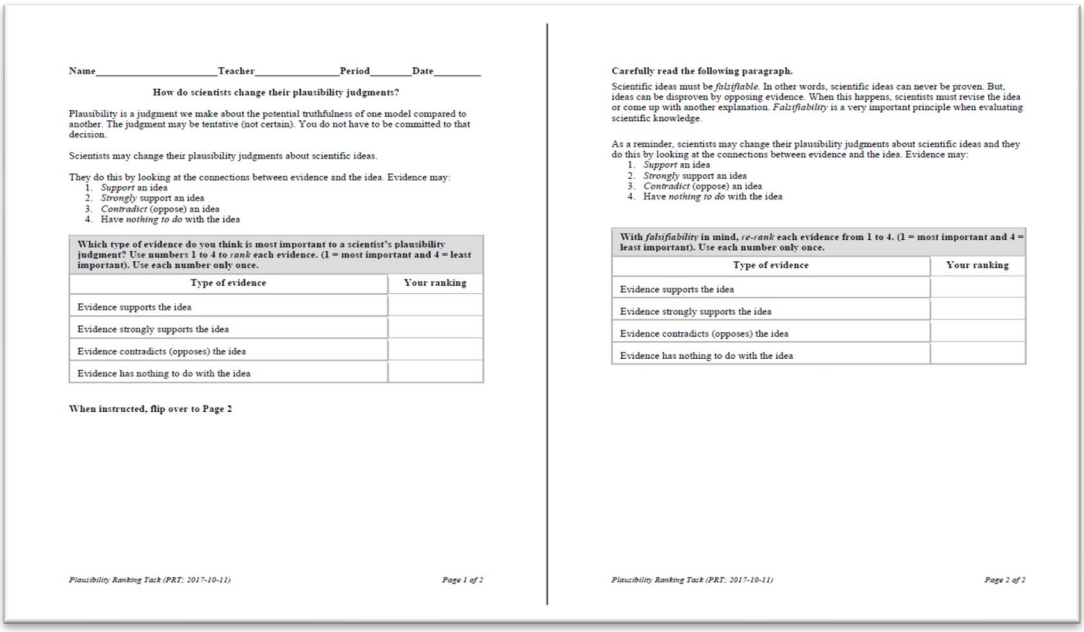
The MEL Project Teacher Guide

Pre-constructed MEL (pcMEL)

SCIENCE LEARNING
RESEARCH GROUP

The MEL 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.

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.



Name_____Teacher_____Period_____Date_____

How do scientists change their plausibility judgments?

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:
1. *Support* an idea
2. *Strongly* support an idea
3. *Contradict* (oppose) an idea
4. 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

Plausibility Ranking Task (PRT; 2017-10-11) *Page 1 of 2*

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:
1. *Support* an idea
2. *Strongly* support an idea
3. *Contradict* (oppose) an idea
4. 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	

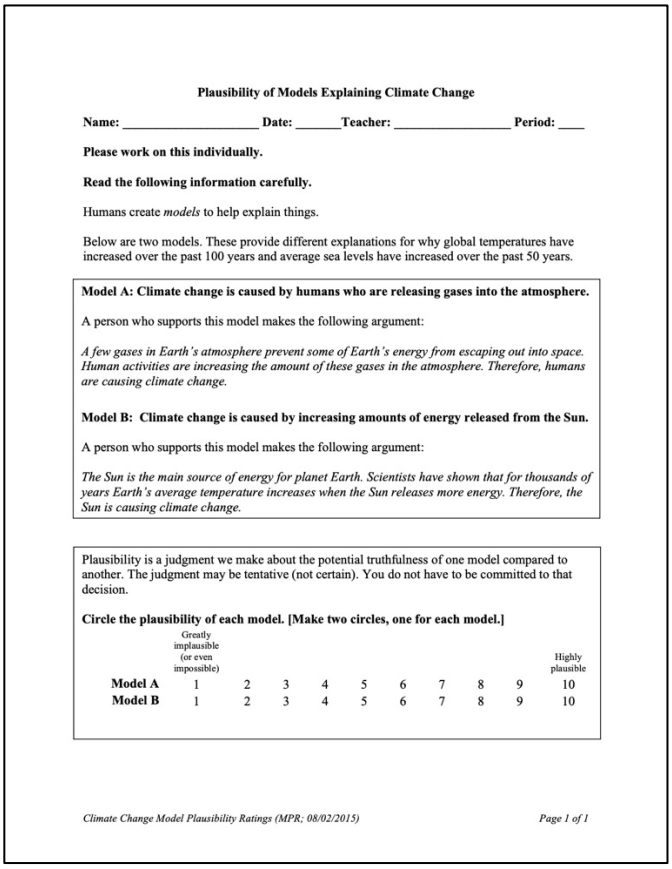
Plausibility Ranking Task (PRT; 2017-10-11) *Page 2 of 2*

Figure 1: Screenshot of the Plausibility Ranking Task forms.

   a. First, have students make an initial ranking of the importance of four categories of connections between evidence and models, where a line of evidence:
      i. strongly supports a model,
      ii. supports a model,
      iii. has nothing to do with a model, or
      iv. contradicts a model.
   b. Second, have the students read the short passage about 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.
   c. Third, conduct a short, whole class discussion with the students about the falsifiability passage.
   d. Fourth, then have the students re-rank the importance of the categories.

> *Guiding Questions:*
> How did you rank the categories and why?
> Why do you think [category] is most important?

2. Rate the plausibility of the two pcMEL models using ***Model Plausibility Ratings*** (MPR) sheet
   Completing this activity takes about 10 minutes and introduces students to the models they will be considering for the pcMEL and re-introduces students to the idea of plausibility judgments. This should be done as the first activity for each pcMEL



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

Climate Change Model Plausibility Ratings (MPR; 08/02/2015) *Page 1 of 1*

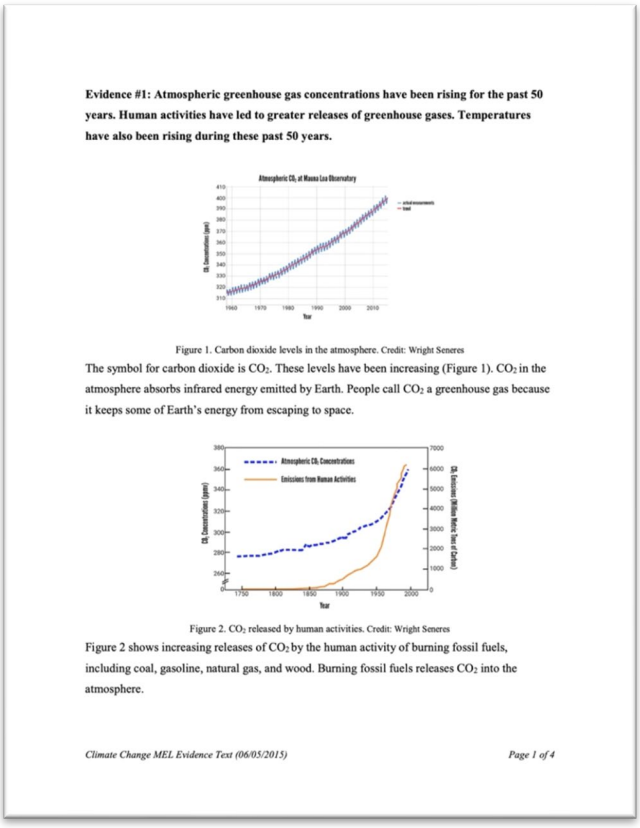
Figure 2: Screenshot of the Model Plausibility Rating task of Climate Change pcMEL.

   a. Students individually read about the two models.
   b. Hold a class discussion to answer questions about the models.
   c. Have the students rate the plausibility of each model...make sure the draw a circle around one number for each model (there should be two circles).

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

   Introduce students to the four Evidence Statements and Evidence Texts. 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.

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



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 Seneres

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.

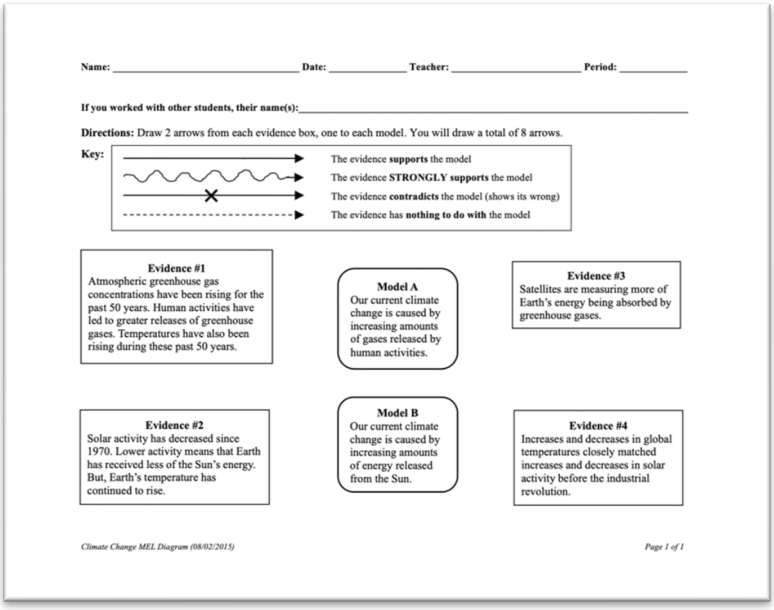
Figure 2. CO_2 released by human activities. Credit: Wright Seneres

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.

Climate Change MEL Evidence Text (06/05/2015) *Page 1 of 4*

Figure 3: Screenshot of one pcMEL Climate Change Evidence Text

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 complete the MEL diagram following the steps below.


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.

Climate Change MEL Diagram (08/02/2015) *Page 1 of 1*

Figure 3: Screenshot of the Climate Change 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.
   b. 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; and dashed arrows indicate the evidence has nothing to do with the model.
   c. Have 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.

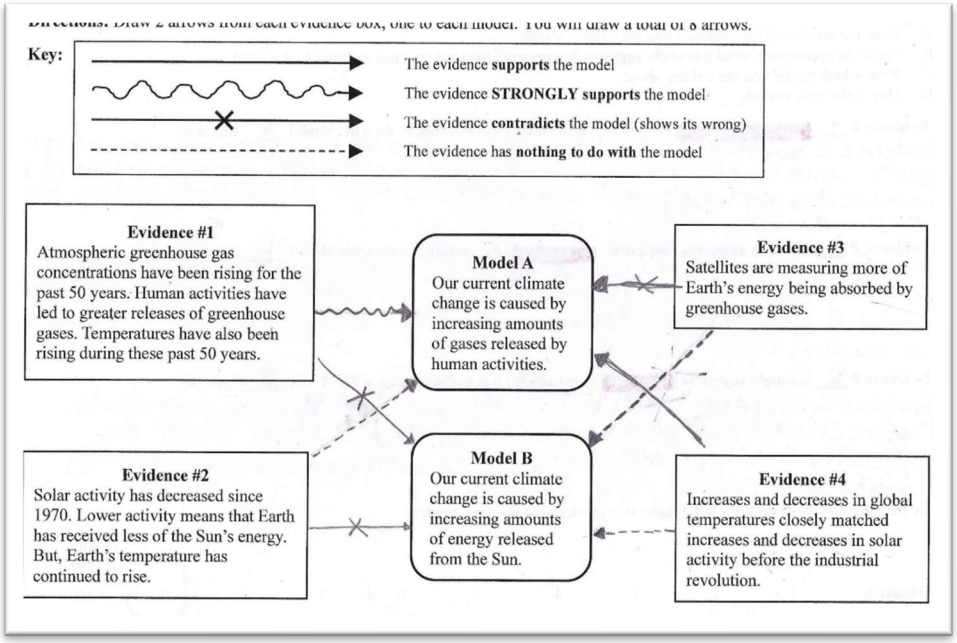
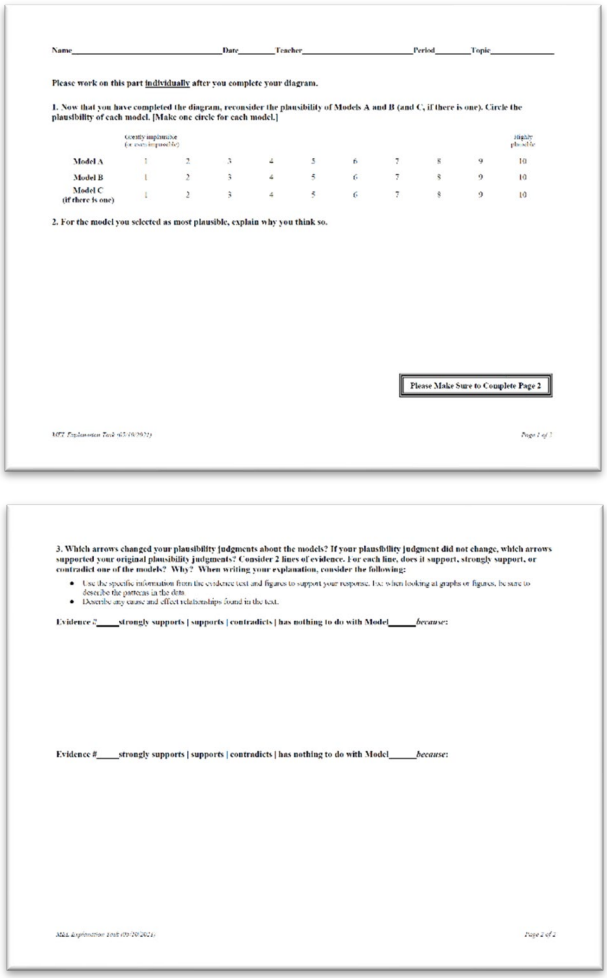


Figure 4: Screenshot of the completed Climate Change pcMEL Diagram

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 evidence-to-model links that they made on their MEL diagram.

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



Name_____Date_____Teacher_____Period_____Topic_____

Please work on this part individually 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.]

	(entity 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

MEL Explanation Task (6/5/19/2021) Page 1 of 2

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. For 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*:

MEL Explanation Task (09/20/2021) Page 2 of 2

Figure 7: Screenshots of the Explanation Task

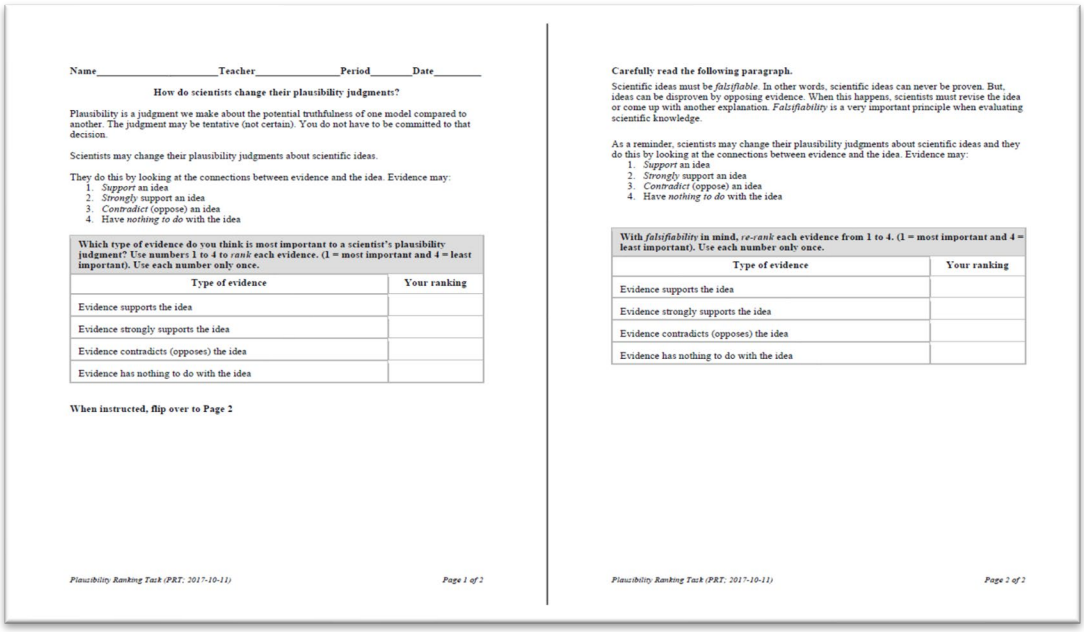
a. Students first re-rate the plausibility of each model. These are the same models present in the *Model Plausibility Ratings* and on the MEL diagrams. They also explain why they believe a particular model is the most plausible.
b. In their written explanations (p.2), students identify each end of the link, with an evidence statement (which are numbered) at one end and the model (which are lettered) at the other.
c. Students write their judgment about the strength of the link (i.e., the evidence strongly supports the model, the evidence supports the model, the evidence has nothing to do with the model, or the evidence contradicts the model).
d. Students then provide a justification for their weighting of link strength.

The MEL Project Teacher Guide

Build A MEL (baMEL)

The MEL 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.

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.



Name_____Teacher_____Period_____Date_____

How do scientists change their plausibility judgments?

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:
1. *Support* an idea
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4. 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
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Plausibility Ranking Task (PRT; 2017-10-11) *Page 1 of 2*

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:
1. *Support* an idea
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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
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Evidence has nothing to do with the idea	

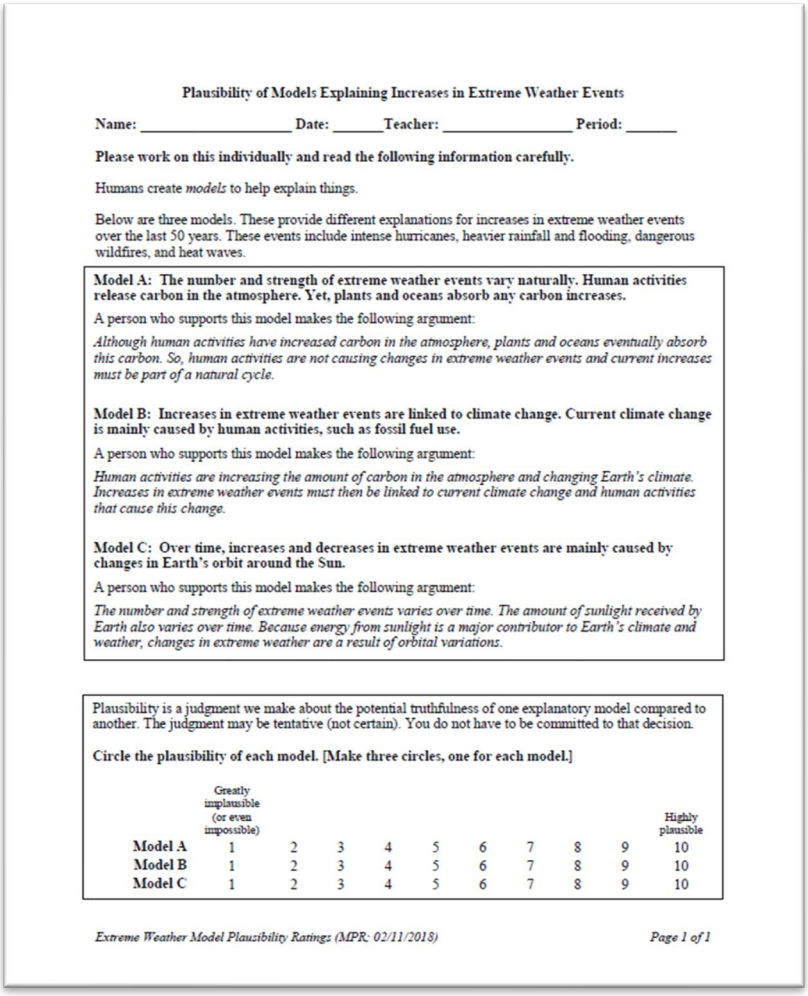
Plausibility Ranking Task (PRT; 2017-10-11) *Page 2 of 2*

Figure 1: Screenshot of the Plausibility Ranking Task.

   a. First, have students make an initial ranking of the importance of four categories of connections between evidence and models, where a line of evidence:
      i. strongly supports a model,
      ii. supports a model,
      iii. has nothing to do with a model, or
      iv. contradicts a model.
   b. Second, have the students read the short passage about 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.
   c. Third, conduct a short, whole class discussion with the students about the falsifiability passage.
   d. Fourth, then have the students re-rank the importance of the categories.

> *Guiding Questions:*
> How did you rank the categories and why?
> Why do you think [category] is most important?

2. Rate the plausibility of the three baMEL models using ***Model Plausibility Ratings*** (MPR) sheet
   Completing this sheet takes about 10 minutes and introduces students to the models they will be considering for the baMEL and re-introduces students to idea of plausibility judgments. This should be done as the first activity for each baMEL.



Plausibility of Models Explaining Increases in Extreme Weather Events

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

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

Humans create *models* to help explain things.

Below are three models. These provide different explanations for increases in extreme weather events over the last 50 years. These events include intense hurricanes, heavier rainfall and flooding, dangerous wildfires, and heat waves.

Model A: The number and strength of extreme weather events vary naturally. Human activities release carbon in the atmosphere. Yet, plants and oceans absorb any carbon increases.

A person who supports this model makes the following argument:

Although human activities have increased carbon in the atmosphere, plants and oceans eventually absorb this carbon. So, human activities are not causing changes in extreme weather events and current increases must be part of a natural cycle.

Model B: Increases in extreme weather events are linked to climate change. Current climate change is mainly caused by human activities, such as fossil fuel use.

A person who supports this model makes the following argument:

Human activities are increasing the amount of carbon in the atmosphere and changing Earth's climate. Increases in extreme weather events must then be linked to current climate change and human activities that cause this change.

Model C: Over time, increases and decreases in extreme weather events are mainly caused by changes in Earth's orbit around the Sun.

A person who supports this model makes the following argument:

The number and strength of extreme weather events varies over time. The amount of sunlight received by Earth also varies over time. Because energy from sunlight is a major contributor to Earth's climate and weather, changes in extreme weather are a result of orbital variations.

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 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

Extreme Weather Model Plausibility Ratings (MPR: 02/11/2018) *Page 1 of 1*

Figure 2: Screenshot of the Model Plausibility Rating task of Extreme Weather baMEL.

a. Students individually read about the three models and plausibility.
b. Hold a class discussion to answer questions about the model and plausibility.
c. Have the students rate the plausibility of each model. Make sure students draw a circle around one number for each model (there should be three circles).

3. Use the ***baMEL*** lines of evidence and three models to construct a ***MEL diagram.*** This is a completely new activity and the essence of the new build-a-MEL (baMEL). We anticipate that this, along with the MPR (see above) will take one or two traditional class periods (~50 minutes). The students should have the opportunity to consider and discuss all the different models and lines of evidence when making their selections.
    a. Give students the model cards and the 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.

Accommodation Hint
Laminated cards can be annotated with dry erase markers by students with language difficulties.

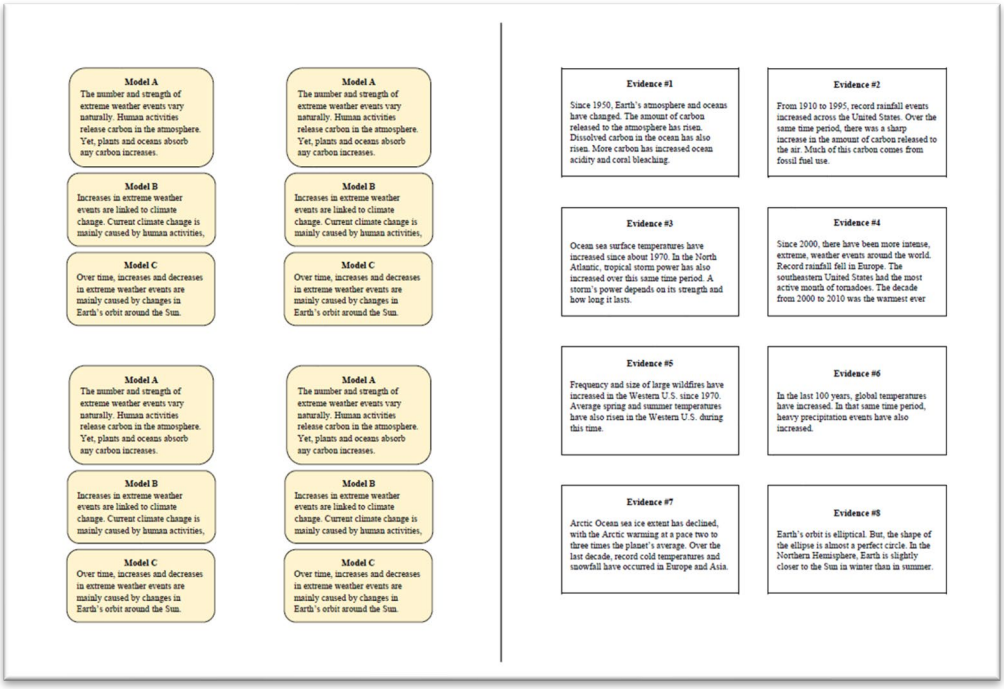
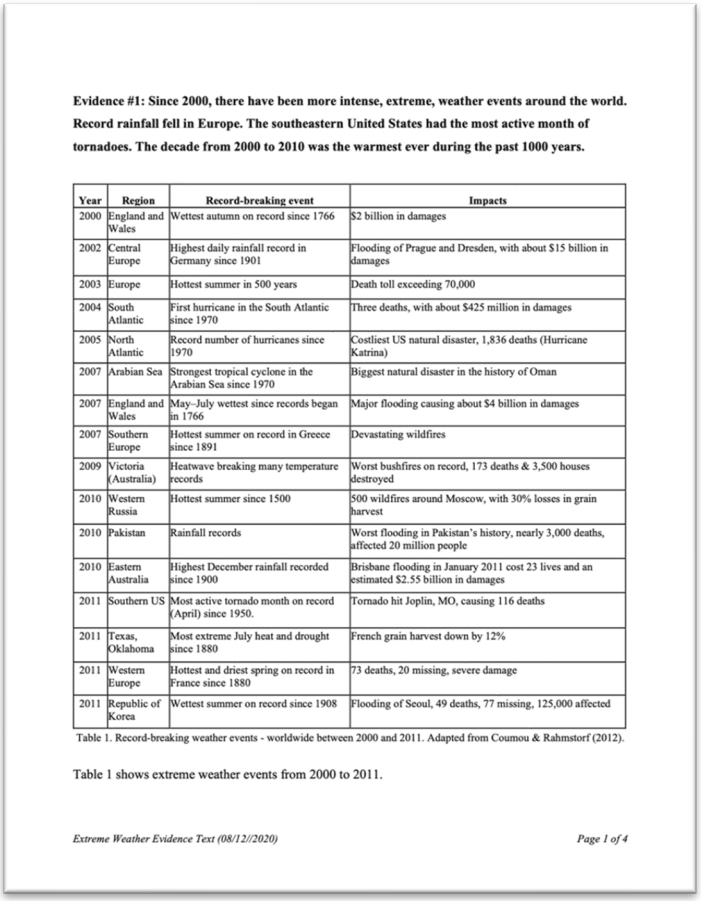


Figure 3: Screenshot of baMEL evidence texts and models cards sheet.

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

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

Topic Hint: Fossils
Evidence 5 refers to coral reefs. Students might be confused by the fact that reefs are on the Earth's surface even though they are under water.



Evidence #1: Since 2000, there have been more intense, extreme, weather events around the world. Record rainfall fell in Europe. The southeastern United States had the most active month of tornadoes. The decade from 2000 to 2010 was the warmest ever during the past 1000 years.

Year	Region	Record-breaking event	Impacts
2000	England and Wales	Wettest autumn on record since 1766	$2 billion in damages
2002	Central Europe	Highest daily rainfall record in Germany since 1901	Flooding of Prague and Dresden, with about $15 billion in damages
2003	Europe	Hottest summer in 500 years	Death toll exceeding 70,000
2004	South Atlantic	First hurricane in the South Atlantic since 1970	Three deaths, with about $425 million in damages
2005	North Atlantic	Record number of hurricanes since 1970	Costliest US natural disaster, 1,836 deaths (Hurricane Katrina)
2007	Arabian Sea	Strongest tropical cyclone in the Arabian Sea since 1970	Biggest natural disaster in the history of Oman
2007	England and Wales	May–July wettest since records began in 1766	Major flooding causing about $4 billion in damages
2007	Southern Europe	Hottest summer on record in Greece since 1891	Devastating wildfires
2009	Victoria (Australia)	Heatwave breaking many temperature records	Worst bushfires on record, 173 deaths & 3,500 houses destroyed
2010	Western Russia	Hottest summer since 1500	500 wildfires around Moscow, with 30% losses in grain harvest
2010	Pakistan	Rainfall records	Worst flooding in Pakistan's history, nearly 3,000 deaths, affected 20 million people
2010	Eastern Australia	Highest December rainfall recorded since 1900	Brisbane flooding in January 2011 cost 23 lives and an estimated $2.55 billion in damages
2011	Southern US	Most active tornado month on record (April) since 1950.	Tornado hit Joplin, MO, causing 116 deaths
2011	Texas, Oklahoma	Most extreme July heat and drought since 1880	French grain harvest down by 12%
2011	Western Europe	Hottest and driest spring on record in France since 1880	73 deaths, 20 missing, severe damage
2011	Republic of Korea	Wettest summer on record since 1908	Flooding of Seoul, 49 deaths, 77 missing, 125,000 affected

Table 1. Record-breaking weather events - worldwide between 2000 and 2011. Adapted from Coumou & Rahmstorf (2012).

Table 1 shows extreme weather events from 2000 to 2011.

Extreme Weather Evidence Text (08/12//2020) *Page 1 of 4*

Figure 4: Screenshot of one baMEL Extreme Weather Statement and Evidence Text.

d. 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.
e. It may work best if students work in groups of three or four in constructing a MEL.
f. 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).

Teacher Hint

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.

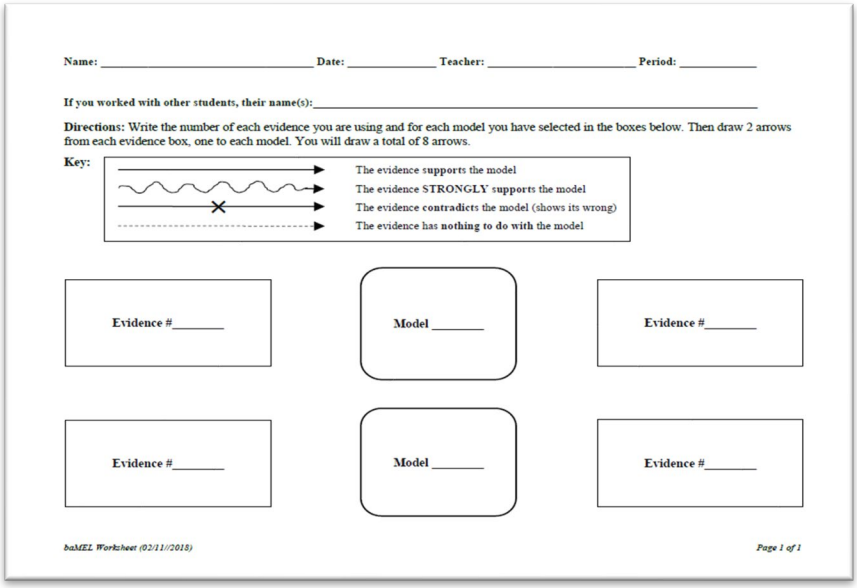


Figure 5: Screenshot of the blank baMEL Diagram used for all topics.

4. Now students are ready to complete their own ***MEL diagram***.
   Along with completing the Explanation Task (see below for a student example from the Extreme Weather baMEL), drawing arrows on the MEL diagram and discussing arrows in groups takes just under one traditional class period (~30-40 minutes).

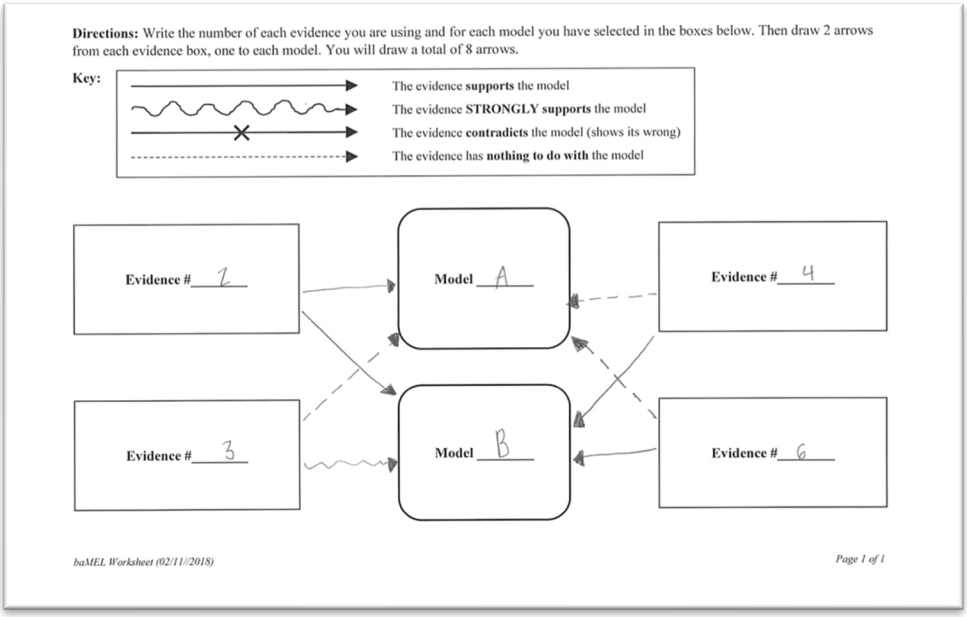
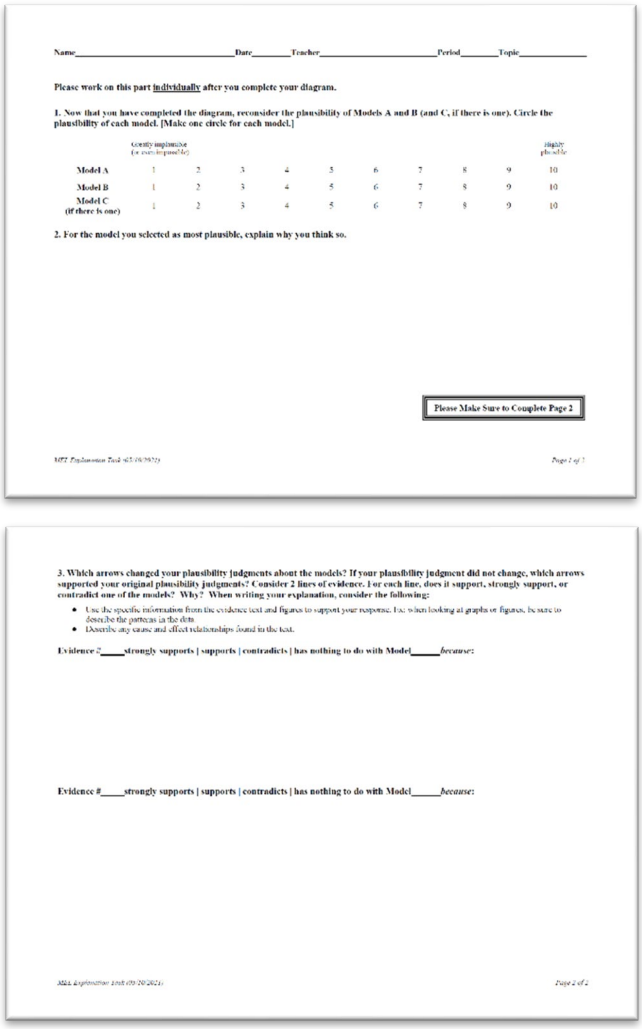


Figure 6: Screenshot of the completed Extreme Weather baMEL Diagram.

   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 a model.
   b. 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; and dashed arrows indicate the evidence has nothing to do with the model.
   c. Have 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.

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 evidence-to-model links that they had made on their MEL diagram.

> *Conversation Tip*
> Students may ask which is "scientifically correct" model. Remind them that they have pieces of evidence to help them form their own ideas about that.



Name_____Date_____Teacher_____Period_____Topic_____

Please work on this part individually 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.]

	Comletely implausible (or even impossible)									Highly plausible
Model A	1	2	3	4	5	6	7	8	9	10
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2. For the model you selected as most plausible, explain why you think so.

Please Make Sure to Complete Page 2

MEL Explanation Task v03/19/2021 *Page 1 of 2*

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*:

MEL Explanation Task (03/20/2021) *Page 2 of 2*

Figure 7: Screenshot of the Explanation Task.

a. Students first re-rate the plausibility of each model, including the one they did not use in their diagram. 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 identify each end of the link, with an evidence statement (which are numbered) at one end and the model (which are lettered) at the other.
c. Students write their judgment about the strength of the link (i.e., the evidence strongly supports the model, the evidence supports the model, the evidence has nothing to do with the model, or the evidence contradicts the model).
d. Students then provide a justification for their weighting of link strength.

The MEL Project Teacher Guide

Virtual pcMEL

SCIENCE LEARNING
RESEARCH GROUP

The pre-constructed MEL (pcMEL) 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 pcMEL activities in virtual settings.

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.

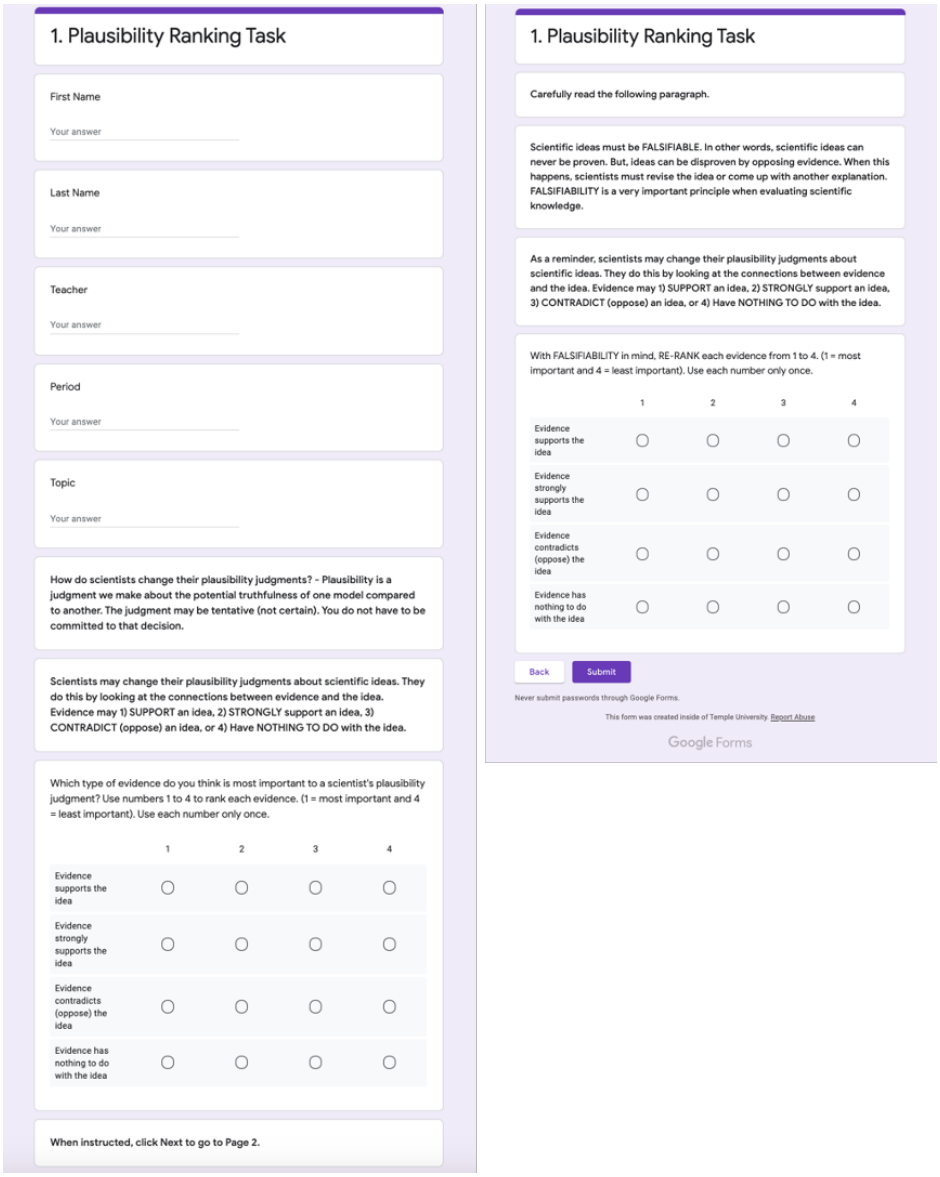


Figure 1: Screenshot of the Plausibility Ranking Task Google Form.

a. First, have students make an initial ranking of the importance of four categories of connections between evidence and models, where a line of evidence:
   i. strongly supports a model,
   ii. supports a model,
   iii. has nothing to do with a model, or
   iv. contradicts a model.

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

> *Guiding Questions:*
> How did you rank the categories and why?
> Why do you think [category] is most important?

b. Second, have the 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.
c. Third, conduct a short, whole class discussion with the students about the falsifiability passage.
d. Fourth, then have the 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.

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

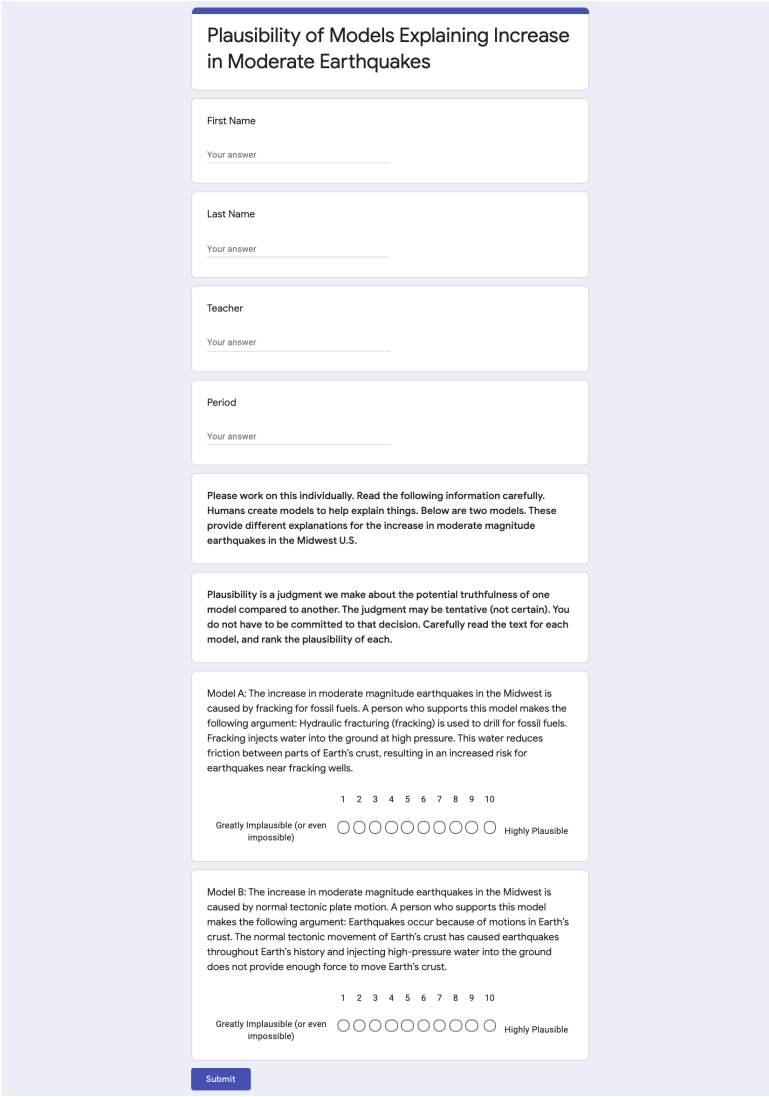
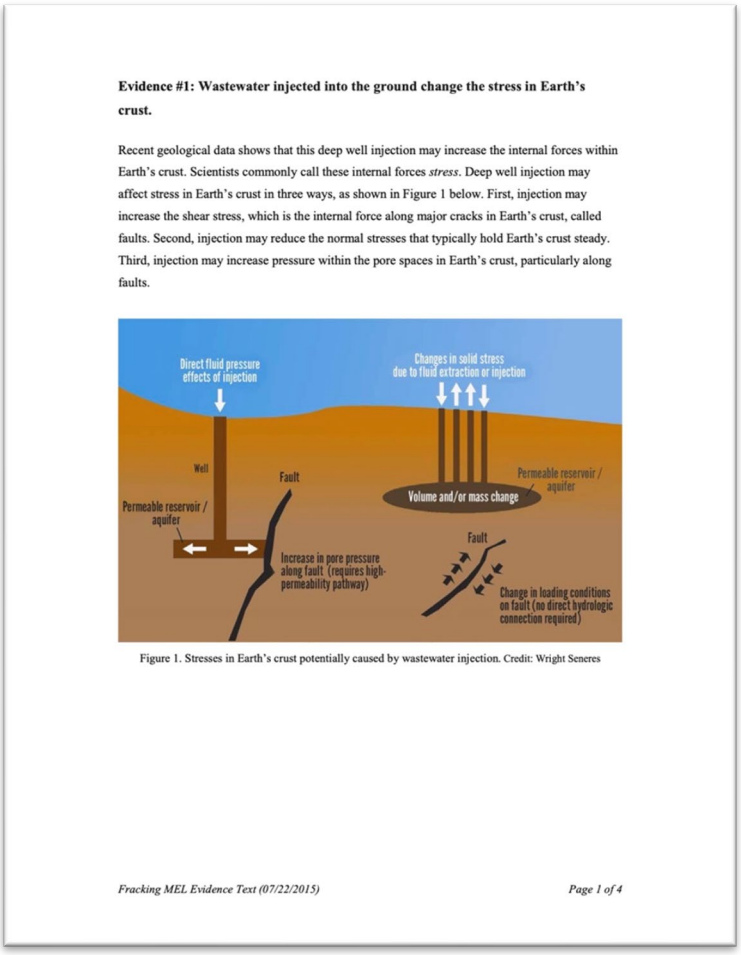


Figure 2: Screenshot of the Fracking Model Plausibility Ratings Google Form.

d. Students individually read about the two pcMEL models and plausibility.
e. Hold a class discussion to answer questions about the models and plausibility.
f. Have the students rate the plausibility of each model; make sure they select one number for each model.

2. Introduce students to the four ***Evidence Statements and Evidence Texts*** (found in the Google Drive folder for each pcMEL). 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.



Evidence #1: Wastewater injected into the ground change the stress in Earth's crust.

Recent geological data shows that this deep well injection may increase the internal forces within Earth's crust. Scientists commonly call these internal forces *stress*. Deep well injection may affect stress in Earth's crust in three ways, as shown in Figure 1 below. First, injection may increase the shear stress, which is the internal force along major cracks in Earth's crust, called faults. Second, injection may reduce the normal stresses that typically hold Earth's crust steady. Third, injection may increase pressure within the pore spaces in Earth's crust, particularly along faults.

Figure 1. Stresses in Earth's crust potentially caused by wastewater injection. Credit: Wright Seneres

Fracking MEL Evidence Text (07/22/2015) *Page 1 of 4*

Figure 3: Screenshot of one pcMEL Fracking Evidence Statement and Evidence Text.

3. 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 5-1 MEL Diagram slide deck. Ask students to select two models from slide 3 and place them in slide 4 in the 5-1 slide deck. Then ask the students to select four evidence statements they will evaluate and also place them in slide 4 in the 5-1 slide deck. Then have them complete the MEL diagram following the steps below (the MEL diagram template can be found in the Google Drive folder for each pcMEL). This will take about one traditional class period (~50 minutes).

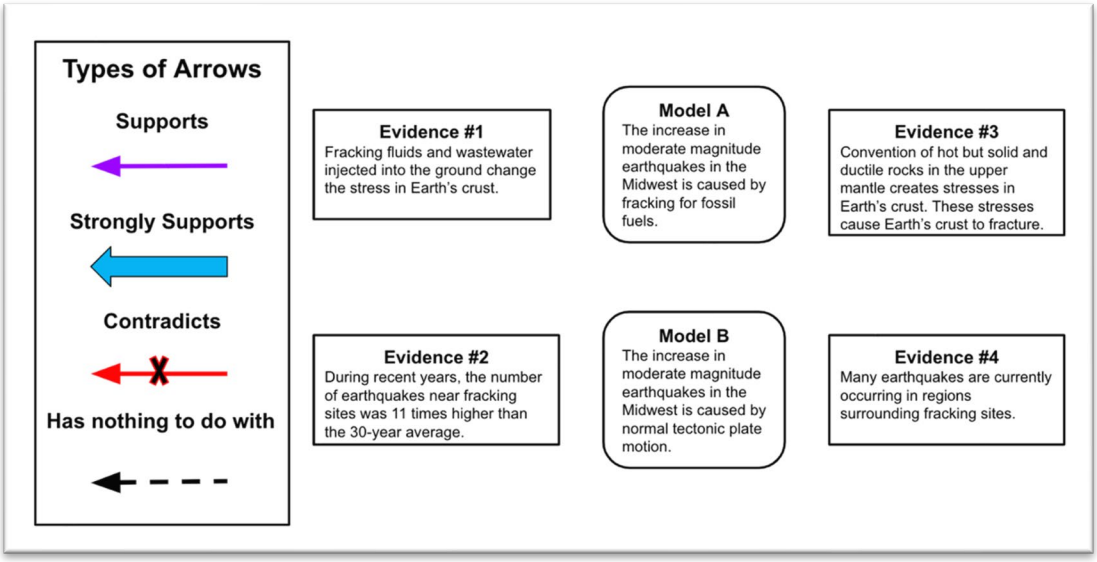


Figure 4: Screenshot of the Fracking pcMEL Diagram template.

   a. 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.
      - 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;
      - and dashed arrows indicate the evidence has nothing to do with the model.
   b. Have students work in teams to discuss the types of connections made between the evidence and models. Ask students to create a team model, and add 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) 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.

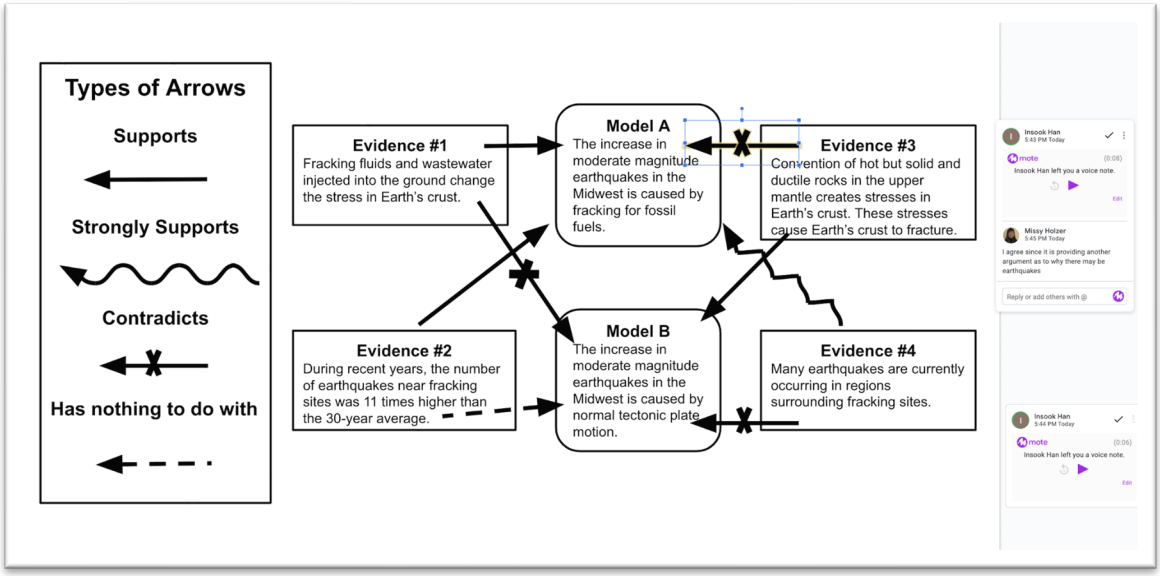


Figure 5: Screenshot of the completed Fracking pcMEL Diagram.

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

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

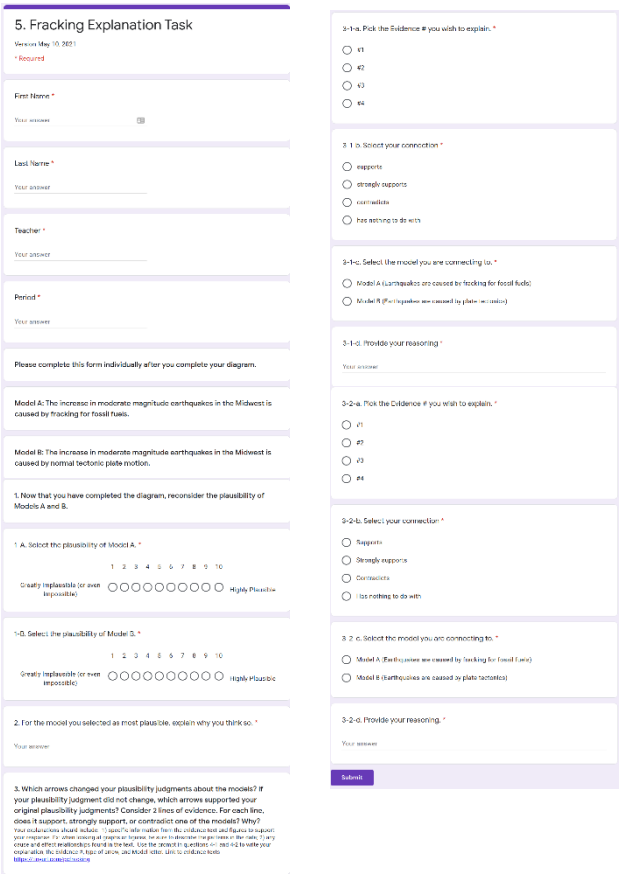


Figure 6: Screenshot of the Explanation Task Google Form

The MEL Project Teacher Guide

Virtual baMEL

SCIENCE LEARNING
RESEARCH GROUP

The 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. This guide will assist in implementing the baMEL activities in virtual settings.

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 baMELs with a given set of students, keep this in mind. This task helps develop understanding about how scientists make judgments about the connections between evidence and models.

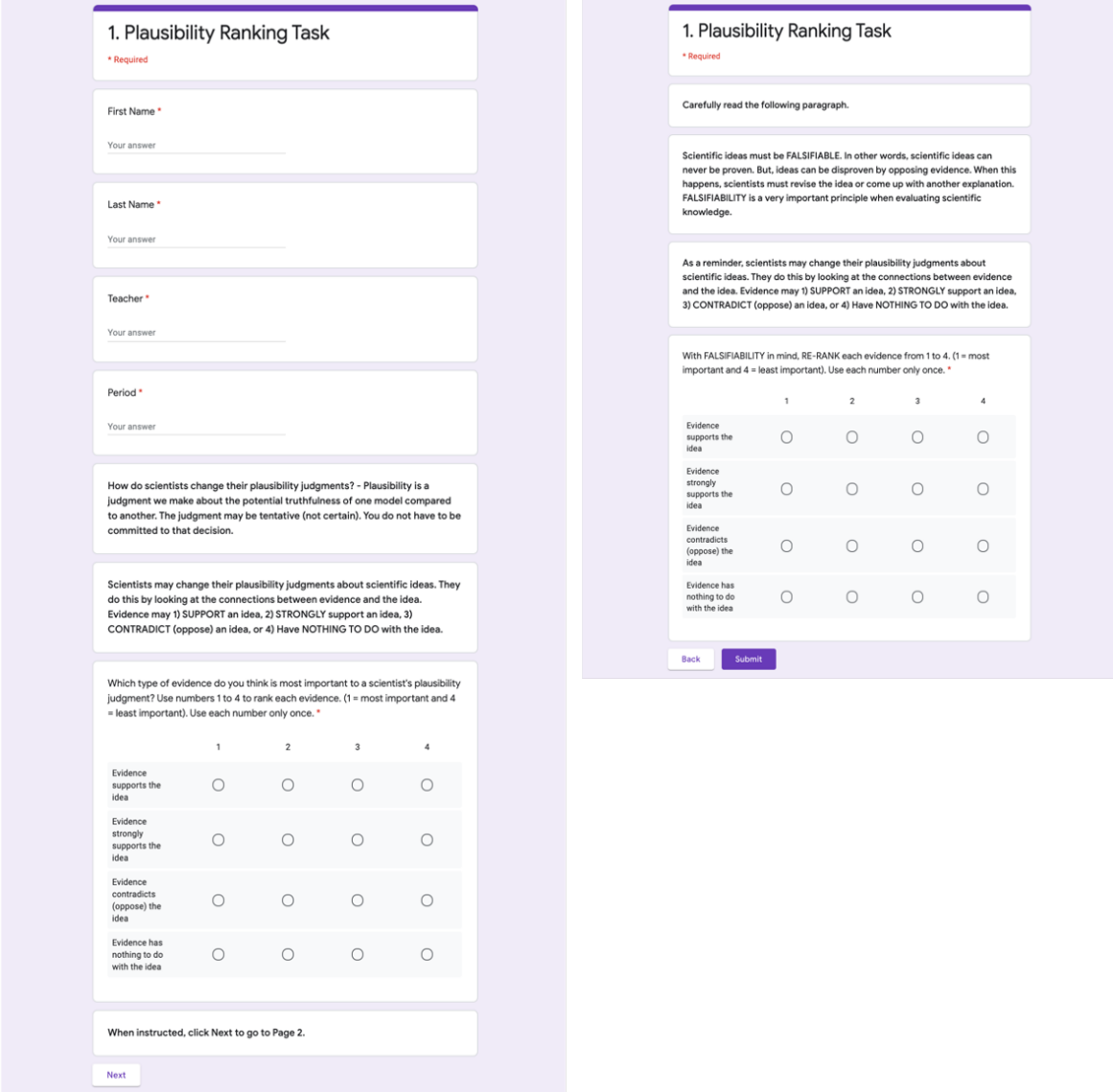


Figure 1: Screenshot of the Plausibility Ranking Task Google Form

a. First, have students make an initial ranking of the importance of four categories of connections between evidence and models, where a line of evidence:
   i. supports a model,
   ii. strongly supports a model,
   iii. contradicts a model, or
   iv. has nothing to do with a model.

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

> *Guiding Questions:*
> How did you rank the categories and why?
> Why do you think [category] is most important?

b. Second, have the 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.
c. Third, conduct a short, whole class discussion with the students about the falsifiability passage.
d. Fourth, then have the 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.

2. Rate the plausibility of the three baMEL models using ***Model Plausibility Ratings*** (MPR) Google Form found in the baMEL Google Drive folder for each baMEL. Completing this sheet takes about 10 minutes and introduces students to the models they will be considering for the baMEL and re-introduces students to the idea of plausibility judgments.

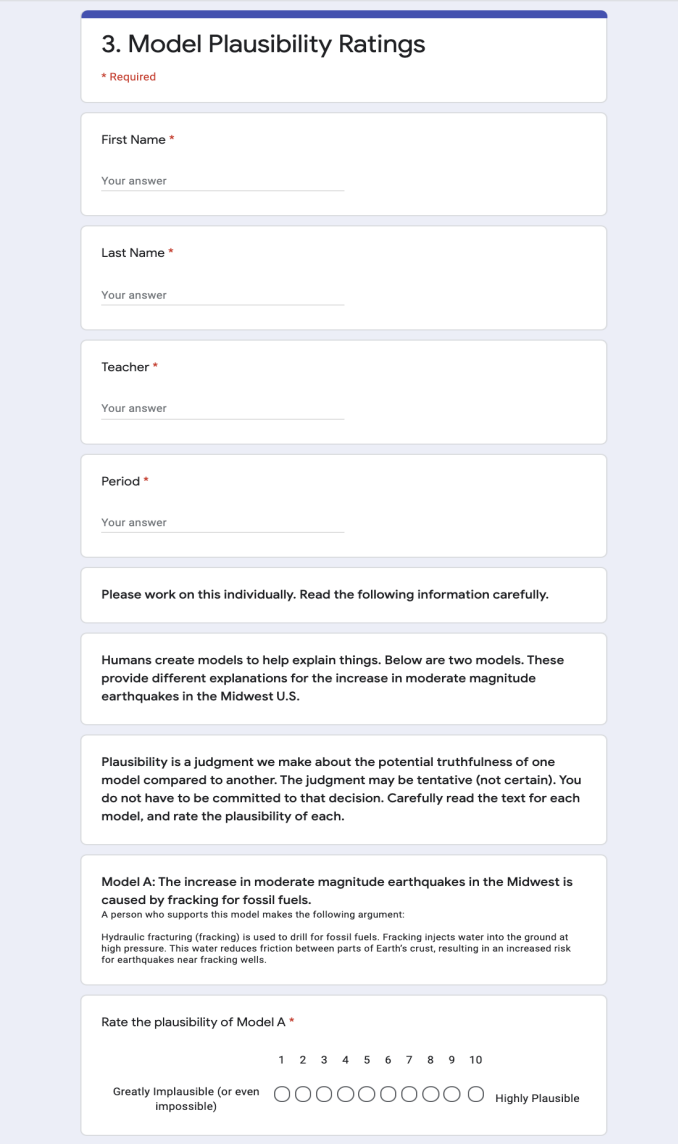
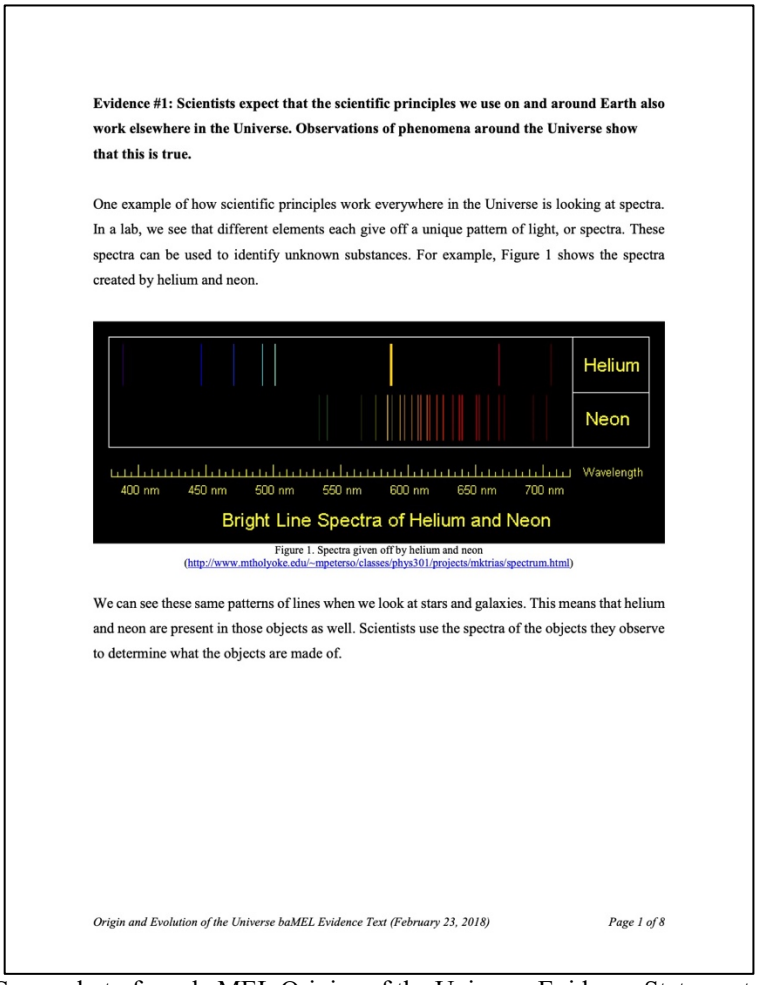


Figure 2: Screenshot of the Model Plausibility Ratings Google Form.

a. Students individually read about the three baMEL models and plausibility.
b. Hold a class discussion to answer questions about the models and plausibility.
c. Have the students rate the plausibility of each model; make sure they select one number for each model.

3. Introduce students to the eight ***Evidence Statements and Evidence Texts*** (found in the Google Drive folder for each 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.



Evidence #1: Scientists expect that the scientific principles we use on and around Earth also work elsewhere in the Universe. Observations of phenomena around the Universe show that this is true.

One example of how scientific principles work everywhere in the Universe is looking at spectra. In a lab, we see that different elements each give off a unique pattern of light, or spectra. These spectra can be used to identify unknown substances. For example, Figure 1 shows the spectra created by helium and neon.

Figure 1. Spectra given off by helium and neon
(http://www.mtholyoke.edu/~mpeterso/classes/phys301/projects/mktrias/spectrum.html)

We can see these same patterns of lines when we look at stars and galaxies. This means that helium and neon are present in those objects as well. Scientists use the spectra of the objects they observe to determine what the objects are made of.

Figure 3: Screenshot of one baMEL Origins of the Universe Evidence Statement and Evidence Text.

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 5-1 MEL Diagram slide deck. Ask students to select two models from slide 3 and place them in slide 4 in the 5-1 slide deck. Then ask the students to choose four of the evidence statements they will evaluate and also place them in slide 4 in the 5-1 slide deck. Then have them complete the MEL diagram following the steps below (the MEL diagram template can be found in the Google Drive folder for each baMEL). This will take about one traditional class period (~50 minutes).

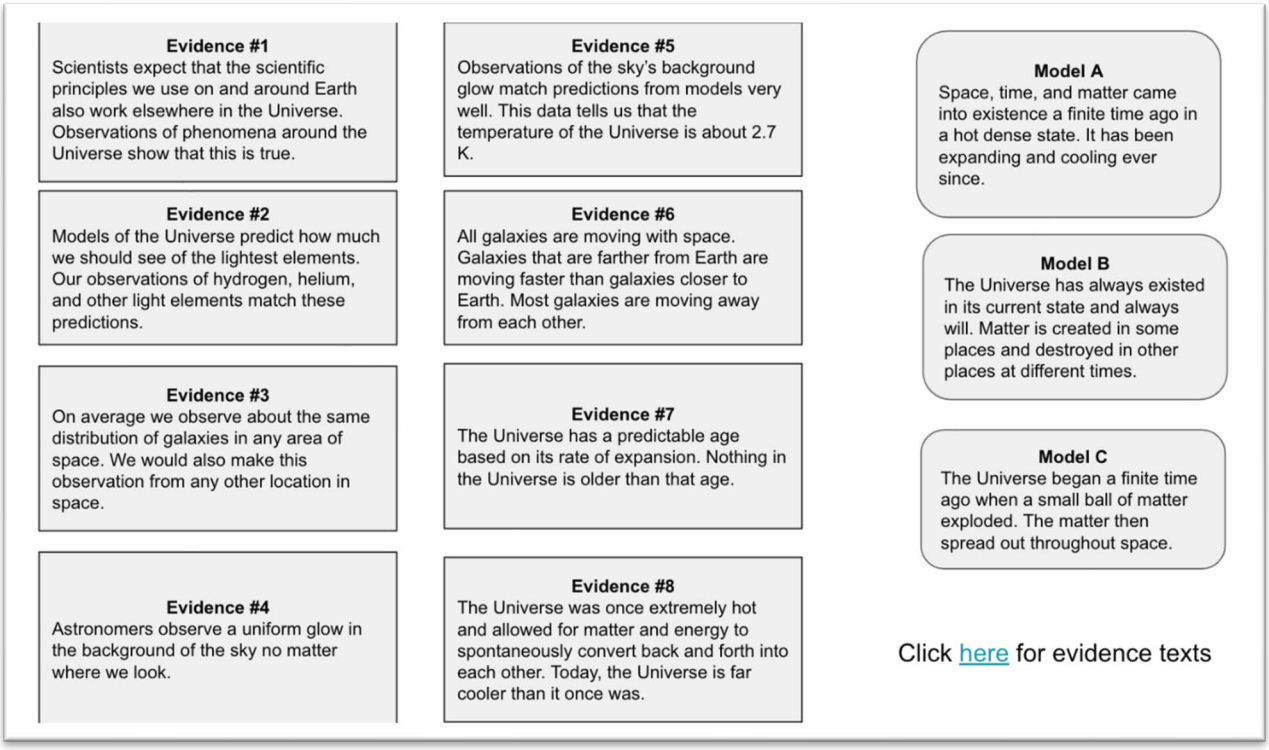


Figure 4: Screenshot of the baMEL models and evidence statements for the Origins of the Universe baMEL.

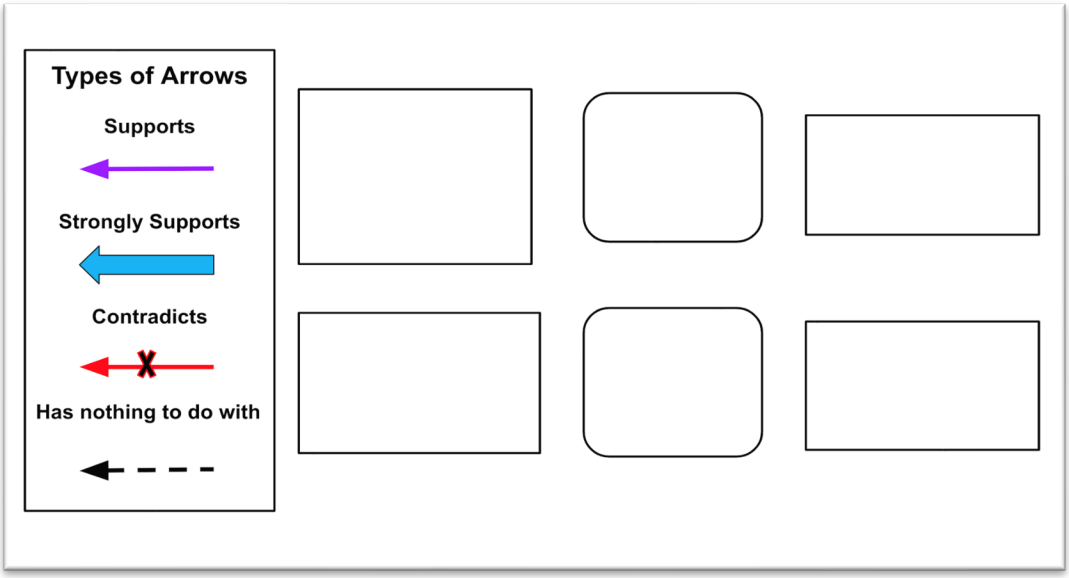


Figure 5: Screenshot of the baMEL Diagram template.

a. Ask students to 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.
    - Straight arrows indicate that evidence supports the model;
    - thick arrows indicate that evidence strongly supports the model;
    - straight arrows with an "X" through the middle indicate the evidence contradicts the model;
    - and dashed arrows indicate the evidence has nothing to do with the model.

b. Have students work in teams to discuss the types of connections made between the evidence and models. Ask students to create a separate team model (use the 5-2 MEL Diagram slide deck), and add 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) Note that students should not feel compelled to go back and change their arrows on their personal MEL diagram if they are different from what they created with their team.

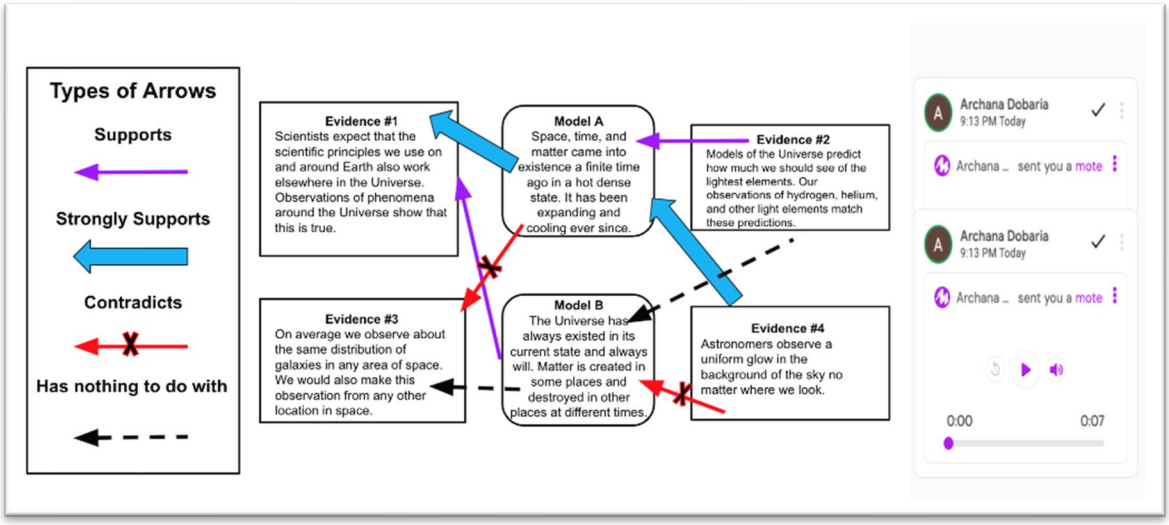


Figure 6: Screenshot of the completed Origins of the Universe baMEL Diagram.

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

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

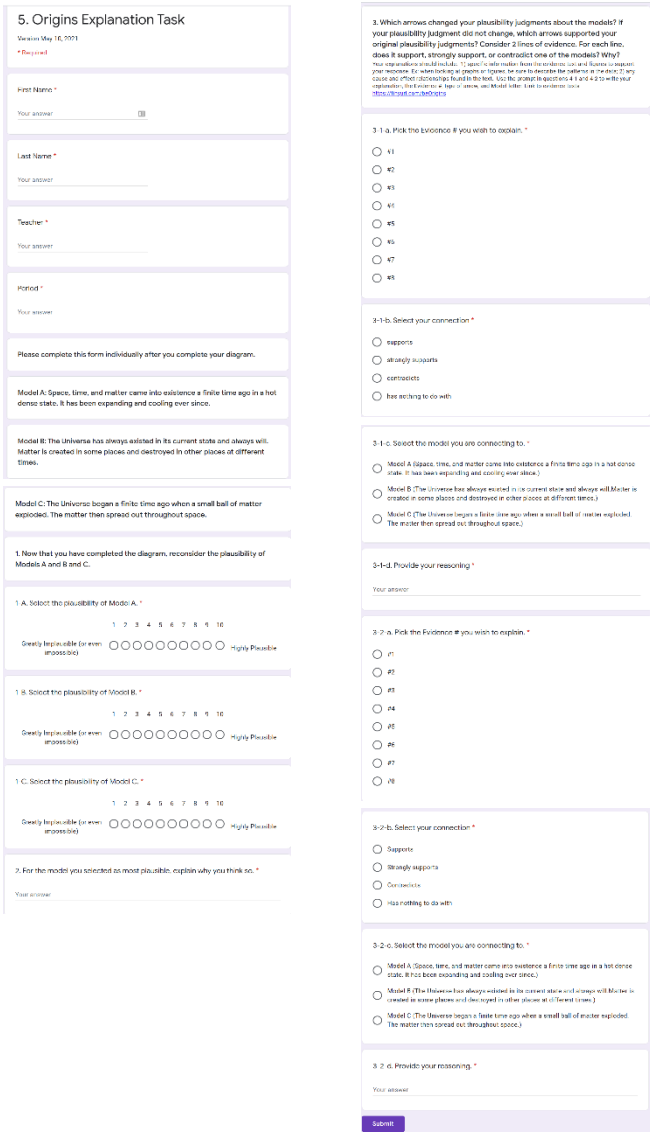


Figure 6: Screenshot of the Explanation Task Google Form.

The MEL Project Teacher Guide

MEL Diagram Transfer Task

SCIENCE LEARNING
RESEARCH GROUP

Here at the MEL Project, we hope that this scaffold will help students think scientifically outside of the classroom walls and the context of the MEL-diagram activities. To that end, we have developed the transfer task found below to give students the opportunity to practice these skills. You may choose to present this activity more than once throughout the school year to reinforce the importance of evaluation in other activities and to measure growth throughout the year.

Background:
Refer to the "Theory to Practice Teacher Guide" for this project, which cites evidence that students can transfer skills gained from engaging in MELs: "Recent theoretical work provides promise for transferring MEL evaluation beyond the context of the activity. Specifically, Nussbaum & Asterhan (2016) suggest that students may become *conceptual agents* (i.e., 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) when they engage in both constructing and using MEL activities. Such construction and use may promote substantial cognitive and agentic engagement (Sinatra et al., 2015), which in turn, could help students internalize the MEL scaffold into a mental representation for application and transfer to real-world situations." This transfer task determines how well students transfer these skills to new situations, such as evaluating the claims in a science article.

Steps for Implementation:

1. Select an article for use by the students. A list of potential articles can be found in the next section, but you may also find others that are newer or more relevant to your specific course curriculum at the time of the activity.

2. Students read the article either by themselves or in small groups using "low-voice" read-aloud technique. Encourage the students to mark up the article to highlight important points. If this is a summative assessment, consider having students work individually.

3. Students complete the table and answer Questions 1-3 on the worksheet found on page 39.

4. Students meet in groups to discuss the article and contents of their tables.
   - 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?

5. Whole Class Discussion
   - Review table contents and answers to questions, followed with questions such as these:

    - 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 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?

Seeking Models and Evidence in Research Articles - *Students*

For this activity, you will first identify the claim or explanatory model presented in a science news article. Then, identify evidence statements that 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.	

Questions:

1. How would you rate the plausibility of the model presented in the article based on the evidence you gathered? Use a scale of 1 (low plausibility) and 10 (highly plausible) and explain why you rated the model as such. If there is an alternative model, also rate the plausibility of the alternative on a scale from 1 to 10.

2. What evidence did you use to rate the plausibility of this model/claim?

3. What questions would you ask the author or scientist about the model and/or lines of evidence?

Possible Transfer Task 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.

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/)