Climate Changes of the Past: Engaging in Evidence-Based Argumentation

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Abstract

Our Earth's climate is dynamic and ever changing. The fossil record provides evidence of early organisms and information about climate changes of the past. By exploring evidence of variations in the fossil record, students can better understand the issues related to climate change today. In the build-a-MEL activity described here, students are asked to evaluate different lines of evidence and make a judgement about how they connect to alternative explanatory models. Critical thinking skills are enhanced while students engage in a process of negotiation about the evidence, and students are hopefully better prepared to address the complexity of issues related to our current climate change situation from studying fossil evidence.

One of the most controversial topics today in science education is that of climate change. While the evidence is overwhelming that Earth's climate is changing as a result of human activities, there are still some who deny that climate change exists. If we want students to understand current issues associated with climate change, it is easiest to introduce the topic by exploring paleoclimatology—past changes in climate—and more importantly the lines of evidence that help us understand Earth's dynamic past and how its systems change and interact. By exploring fossil evidence, we can gain insight not only into Earth's past, but provide a foundation for understanding current shifts in Earth's climate and the evidence that supports the science.

We have created the Fossils build-a-MEL to scaffold students' understanding of how fossils can provide evidence for the past and to support their development in argumentation skills. The activity follows a similar approach as the Model-Evidence Link (MEL) diagram scaffold (Lombardi, 2016) and other build-a-MELs (baMELs; see other articles in this issue).

Support the Standards with the Fossils build-a-MEL

Exploring paleoclimate with fossil evidence crosses disciplinary boundaries in science. Understanding past life forms and what they tell us about the climates they lived in can be studied through different disciplines. In life science, adaptations that help organisms thrive in specific ecosystems provide explanatory evidence to understanding the connections between life and climate. The relationship between past life forms and their environments can be approached through exploring the cross-cutting concept of structure and function. For example, the process of leaf-margin analysis provides information about past climates from leaf fossils because in cooler environments leaves often have more toothed edges, allowing an increased surface area for photosynthesis. In warmer climates, there is no need for such an adaptation as there is ample yearly

Table 1. High School NGSS Standards in Life Science for Fossils build-a-MEL

LS4-6: Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.

Science and Engineering Practices	Disciplinary Core Idea	Cross-Cutting Concepts
• Analyzing & Interpreting Data • Engaging in Argument from Evidence	**LS4.c: Adaptation** • Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline and sometimes the extinction of some species.	• Cause & Effect • Stability & Change

Table 2. High School NGSS Standards in Earth Science for Fossils build-a-MEL

ESS2-7: Construct an argument based on evidence about the simultaneous coevolution of Earth's system and life on Earth.

Science and Engineering Practices	Disciplinary Core Idea	Cross-Cutting Concepts
• Analyzing & Interpreting Data • Engaging in Argument from Evidence	**ESS2.e: Biogeology** • The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual co-evolution of Earth's surface and the life that exists on it.	• Cause & Effect • Stability & Change

sunlight. By studying changes in the ratio of toothed to smooth edges in leaf fossils, scientists can understand how environments have changed over time, depending on the strata in which leaf fossils have been found. NGSS standards for high school life science related to adaptations can be explored by discussing fossils as evidence of past climates, and how changes in the environment result in populations of different organisms, each uniquely adapted to survive in specific ecosystems (see Table 1; NGSS Lead States, 2013).

Paleoclimatology is also an important concept in the NGSS standards for Earth science as students explore system interactions. The fossil record provides us with a treasure trove of evidence for continental drift, as well as how environments in which fossils are found have changed. For example, fossils of tropical plants are often found in taiga biomes, indicating a warmer past environment. NGSS high school standards in Earth Systems can be explored when examining the types of fossils found in layers of sedimentary rock and inferring what they tell us about climate change in the past (see Table 2).

The activity described below is well grounded in three-dimensional instruction; each content standard is matched with the appropriate cross-cutting concepts and science practices that should be emphasized. The two cross-cutting concepts of *cause and effect* and *stability and change* are critical components of the activity as students consider the evidence that fossils provide for past climate change. Additionally, specific science practices are interwoven. These include *analyzing and interpreting data*, which is an important component of all MEL activities, and *engaging in argument from evidence*, a critical practice for students as they negotiate the connections between evidence and alternative explanatory models.

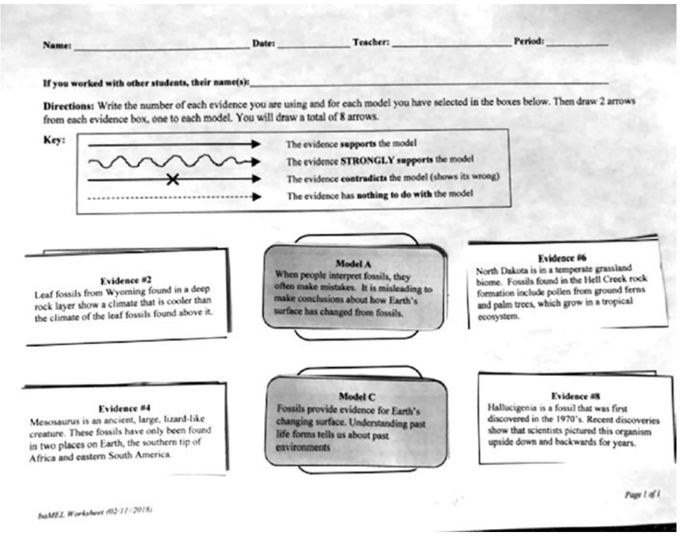
The main activity in this, or any, build-a-MEL (baMEL) is for students to engage in the scientific practice of constructing arguments from evidence. The MEL and baMEL activities, such as the Fossils baMEL, provide both the scaffold and the opportunity for negotiation that can be instrumental in building these skills as students work in small groups throughout the activity.

Table 3. Models for the Fossils build-a-MEL

Model	Statement
Model A	When people interpret fossils, they often make mistakes. It is misleading to make conclusions about how Earth's surface has changed from fossils.
Model B	Many organisms' fossils are missing from the fossil record. We cannot make any conclusions about Earth's past environments from fossils.
Model C	Fossils provide evidence for Earth's changing surface. Understanding past life forms tells us about past environments.

Selecting the Models and Evidence

In the Fossils baMEL activity, students start by reviewing three potential scientific explanations that connect fossils to their environment. These are shown in Table 3. Individually, students first rate the plausibility of each model, then must agree on which two models to choose for the activity. Sometimes students choose the


Name: ______ Date: ______ Teacher: ______ Period: ______

If you worked with other students, their name(s): ______

Directions: Write the number of each evidence you are using and for each model you have selected in the boxes below. Then draw 2 arrows from each evidence box, one to each model. You will draw a total of 8 arrows.

Key:
The evidence **supports** the model
The evidence **STRONGLY supports** the model
The evidence **contradicts** the model (shows its wrong)
The evidence has **nothing to do with** the model

Evidence #2
Leaf fossils from Wyoming found in a deep rock layer show a climate that is cooler than the climate of the leaf fossils found above it.

Model A
When people interpret fossils, they often make mistakes. It is misleading to make conclusions about how Earth's surface has changed from fossils.

Evidence #6
North Dakota is in a temperate grassland biome. Fossils found in the Hell Creek rock formation include pollen from ground ferns and palm trees, which grow in a tropical ecosystem.

Evidence #4
Mesosaurus is an ancient, large, lizard-like creature. These fossils have only been found in two places on Earth, the southern tip of Africa and eastern South America.

Model C
Fossils provide evidence for Earth's changing surface. Understanding past life forms tells us about past environments

Evidence #8
Hallucigenia is a fossil that was first discovered in the 1970's. Recent discoveries show that scientists pictured this organism upside down and backwards for years.

baMEL Worksheet (02/11/2018) *Page 1 of 1*

Figure 1. Fossil baMEL Diagram with Model and Evidence Cards

Table 4. Lines of Evidence for Fossils build-a-MEL

Evidence	Statement
Evidence #1	Trilobites were small animals that lived at the bottom of the ocean. They fed on organic matter in sediment on the ocean floor. Because trilobite fossils are so abundant and well preserved in the limestone and shale rock of Ohio, they were officially named the state fossil.
Evidence #2	Leaf fossils from Wyoming found in a deep rock layer show a climate that is cooler than that of the fossils found above it.
Evidence #3	The Svalbard forest in Arctic Norway is filled with fossils of tropical trees, called Lycopsid. These trees lived hundreds of millions of years ago.
Evidence #4	Mesosaurus is an ancient, large, lizard-like creature. These fossils have only been found in two places on Earth, the southern tip of Africa and eastern South America.
Evidence #5	Fossils of coral reefs have been found in deep water off the coast of Texas. Coral reefs require sunlight to form. Sunlight cannot reach deep water. These coral reefs are about 19,000 years old.
Evidence #6	North Dakota is in a temperate grassland biome. Fossils found in the Hell Creek rock formation include pollen from ground ferns and palm trees, which grow in a tropical ecosystem.
Evidence #7	Many large geographic areas, like the Blue Ridge and Piedmont regions in Georgia, are made up of metamorphic and igneous rock. Fossils are not usually found in these types of rock.
Evidence #8	Hallucigenia is a fossil that was first discovered in the 1970's. Recent discoveries show that scientists pictured this organism upside down and backwards for years.

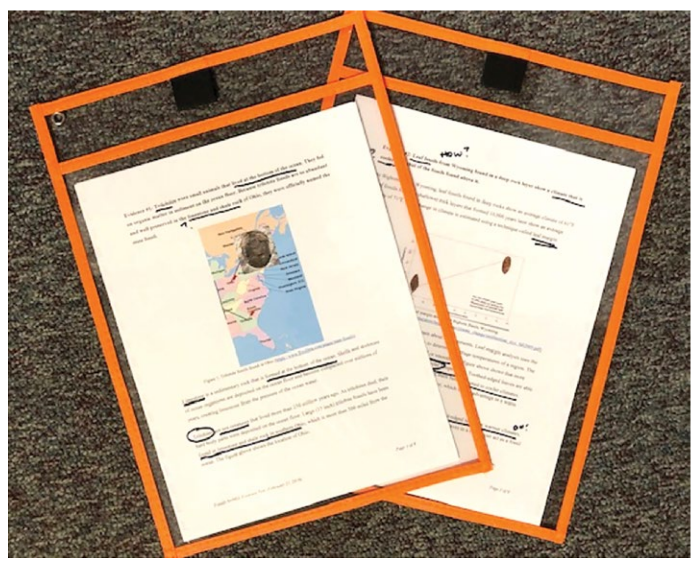


Figure 2. Marking up the Evidence Text

models based on which ones they think are most plausible, other times on those they think are most interesting. Once a decision is made, students select cards based on their choice of models and place them in the center of their MEL diagram handout for reference throughout the activity (Figure 1).

After choosing models to compare, students are presented with eight evidence texts, four of which will be used for the MEL diagram in the activity. These lines of evidence include several examples of fossils found in different locations, and provide information about past environments that are different from current conditions where the fossils were found. Depending on the models selected, different lines of evidence may or may not be relevant. The eight different lines of evidence are summarized in Table 4.

With so many lines of evidence to consider, students occasionally get overwhelmed. Therefore, it may be helpful to present the evidence pieces one at a time so that students can become familiar with each text. It is important that all students can evaluate and discuss the relationship of each line of evidence to each of the two chosen competing explanatory models. Start by presenting each piece separately, projecting a visual for each evidence text and have a conversation, either in small or large groups, to discuss what each means. One strategy for making it easy for students to work with these texts is to slip each into a plastic sheet protector so that students can mark important phrases or make notes with a Vis-à-vis pen (see Figure 2). Make sure students understand the terms used and have a chance to engage with the graphics provided. Many students report that they find the lines of evidence with data tables and graphs to be the most important, because they feel this type of support "quantifies" the information and is the most valid for supporting claims. For example, students have reported that maps used in several of the explanation texts provide a visual representation that can help support their claims with greater certainty and will often find those evidence texts the most compelling.

Negotiation and Argumentation

After students have reviewed all eight evidence texts, they are now in a position to decide which four to use for the MEL task. This is where argumentation and negotiation begin. Allow students time to debate the lines of evidence in their groups to decide which are most interesting, relevant, or important for evaluating the models they have chosen. It is important that they come to a consensus about all four pieces of evidence to use, rather than each choosing a different text, to stimulate discussion. Once the decision is made, students should select the corresponding cards for those four lines of evidence and add them to their MEL diagram handout (Figure 1).

Now that the stage is set, students are ready to do the real work of the activity: negotiating the relationship between the four lines of evidence they have selected and the two competing models. Students must decide if each line of evidence supports, strongly supports, contradicts, or has nothing to do with each of the two models. This decision should be a group one, requiring students to negotiate and debate their decisions. For example, in one class students had the following conversation when discussing the relationship between Evidence 2 and Model C:

> Student 1: What do you think?
>
> Student 2: I think it strongly supports it.
>
> Student 1: Why?
>
> Student 2: Because of the strong quantitative evidence that things have changed.
>
> Student 1: I agree with your statement.

In this exchange it is clear to see that a negotiation is occurring while one student makes a claim, and the other challenges it. Not all negotiations are this quick and easy. These same two students also had the following exchange while discussing another line of evidence:

> Student 1: So, do you feel like evidence 2 supports or strongly supports Model C?
>
> Student 2: I don't feel like any of them, well, this has nothing to do with what you just said but, I don't feel like it has anything to do with Model A.

In this exchange one student feels that the evidence supports the model but is unsure whether it "supports" or "strongly supports." The second student provides a different perspective and provides a different choice. As this negotiation plays out, each student presents their claim, cites the evidence, and eventually agrees on a resolution. These types of negotiations not only help students develop the skills necessary for critical discourse, but also better understand the scientific claims and evidence presented in the activity.

Revisiting and Explaining the Models

The final part of any MEL or baMEL activity is to re-evaluate each of the scientific models, based on the evidence presented. Before students complete the task on the handout for the Explanation Task, you'll want to have a conversation with your students. Probe how each of the eight lines of evidence relates to each model and why. Regardless of which models and lines of evidence they selected, discuss all of the connections. While these conversations can be lengthy, it is important for students to hear about both the evidence texts they did and did not select, because other students may provide a compelling argument about an evidence-model connection. For example, students who evaluated Evidence 8 (Table 4) but not Model A (Table 3) might not see how these are connected; or for those who did evaluate this relationship, might mistake the nature of the evidence. It is worth

The Model-Evidence Link (MEL) and build-a-MEL activities can be accessed on our project's website, https://serc.carleton.edu/mel/index.html.

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having an in-depth, whole class conversation about how science changes but that even when we get something wrong, it doesn't automatically mean that the explanation no longer works. Hearing from other students about the models and lines of evidence that they have not examined may influence their final plausibility rating for any of the three models, which is one of the last tasks of the activity. Of course, the nature of science tells us that no single scientist knows the full story, so stress the importance of collaboration and consensus in the scientific community.

Once students have considered the entire scope of the evidence presented, it is time for them to re-evaluate the plausibility of each model. In our experience, shifts in plausibility for the scientific model are usually largest and toward higher values, demonstrating that students are willing to accept that Earth's surface and climate are dynamic and ever-changing. Finally, ask students to explain one of the connections they made between models and evidence. Look to see if they are able to present a claim, support it with evidence, and explain the relationship. Encourage your students to hone their argumentation skills as they complete the Explanation Task.

Conclusion

There is no doubt that students must practice argumentation skills throughout this baMEL activity. Students are asked to make claims and justify the connections between fossil evidence of past climates and current scientific models that present Earth's climate as dynamic and ever-changing. As they review the fossil evidence that helps us understand past shifts in climate, they begin to build an understanding of how scientists know what they know and how they build support for explanatory models using evidence. Through making evidence-based claims, students participate in the scientific practice of argumentation and begin to see how scientists co-construct evidence-based explanations of scientific phenomena. If students can accept the premise that Earth's climate is constantly changing and understand how we know about past changes, then they are ready to discuss our current climate change situation and, hopefully, the reasons to be alarmed about the evidence and implications related to it.

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