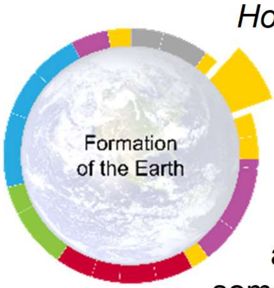
<u>Building the Model</u>: Formation of the Earth

How do you build the model with your students (in Learning Segment 08)?



Introduction

Tracking ideas and building models in the classroom presents challenges whether you are comfortable with models and modeling or you are just learning to engage your students in this practice. MBER presents models as a public, collective-generated set of ideas used to make sense of (to explain) something we've observed in the natural world. The learning segments (lesson sequences) are thus designed to first engage students in wondering about a phenomenon (P), then asking a particular question (Q) that focuses attention to a particular aspect of that phenomenon and finally working to develop a set of ideas, a model (M), that answers our question and/or explains the phenomenon. This P-Q-M design approach will repeat time and again in the MBER Living Earth curricular year, with models generally mapping to units.

The Formation of the Earth unit likely represents your first time engaging in the PQM process and working with a scientific model with your students. As such, we decided to provide you with a more extensive modeling guide for this unit. Additionally, this model is somewhat exceptional in that we don't actually build it (formally) until we've progressed most of the way through the unit. So, it may be important for you to consider its development by looking ahead. In this way, you'll be prepared to help your students track ideas as they develop and to facilitate their own efforts in pulling the pieces together later in the unit.

Formation of the Earth starts with students exploring Earth's uniqueness and asking the question, "How did the unique Earth come to be?" This question really sets us up for *two units* (this unit and the next, Oxygen and Earth's Atmosphere). In Formation of the Earth, we decide that the logical first step is to address how the geosphere—the rocky structure common to all inner planets and many moons of the solar system—might have originated. So, the phenomenon (P) we are really trying to make sense of is that Earth exists as a ball of rocky matter. And the question (Q) is, how did that happen? ("How did the Earth's geosphere originally form?") The remainder of the unit sets us up to build a model that addresses this question. But the path we take is a bit windy.

Instead of immediately generating ideas about how Earth formed, we take a slight detour into an exploration of another feature Earth exhibits in common with the other bodies of the inner solar system—impact craters. In examining these events where rocks from space hit planetary bodies and engaging in a series of activities and labs, we learn a lot that will eventually help us in addressing our driving question about the formation of the geosphere. These explorations go on for a number of days.

When we finally return to our driving question and decide to consider out model, we therefore need a means by which we can leverage what we've already learned. Your students will work to address the driving question, drawing on three sources of inspiration:

1) their general understanding of scientific models;
2) a public list of ideas you've already been tracking on a poster titled, "What we've learned…";
3) and other key ideas that make sense *in their own minds* while engaged in the model-building activity called, "Rewind the Clock".

The “Rewind the Clock” activity in fact provides the platform for building the model. Your students will work to recreate the formation of the Earth in a storyboard/comic strip while consider what they’ve learned in the unit. In completing the activity, they’ll develop initial models and then work with you to generate a first-draft class consensus model. The model then becomes a public artifact to be evaluated and revised. You’ll lead the class through a couple of activities for two model ideas that likely further exploration. And in a final learning segment, you’ll finalize your model for the formation of the geosphere to wrap up the unit.

The components (1-3 listed above) involved in the key model-building discussion are described in more detail below. The descriptions comprise the remainder of the text here followed only by sample wording for the final model (as outlined on the website) as an addendum.

(1) Talking About Models with Your Students

We strongly advise (implore) you to work with your students at the beginning of the year to discuss models and modeling through a series of activities we call “Setting the Stage”. If you jumped directly into the first unit on climate change, you’ll need to at least excerpt some of the activities around developing and using models in the classroom. A component of that work is for the class to understand and agree upon some criteria we can use to decide if our scientific models are “good”. They’ll need this list of criteria with them as they work to build a scientific model for the first time in this unit.

(2) Tracking Ideas During Early Learning Segments in Formation of the Earth

As suggested in the curricular materials, you should come into the rather late model-building section of this unit with a number of ideas already developed. We’ve been trying to understand impact craters, and what we’ve learned can actually be used to understand how the Earth formed. In particular, we have some ideas about matter and energy during impacts that will help us to decide the mechanism for and consequences of a planet built from collisions (the accretionary model).

Though we encourage you to track ideas organically with your students as you move through conversations about learning segments, honoring what comes up in your individual classrooms, there is a minimum set of ideas you’ll want to have explored and recorded prior to taking on building the model.

The minimum poster for “What we’ve learned…” should contain (in some form), the following ideas:

1. Earth shares a rocky structure and craters with the other planets of the inner solar system.
2. Craters on Earth and other planets are likely the product of impacts with space rocks because:
    a. There are still a lot of space rocks in the solar system.
    b. Sometimes space rocks come close enough to Earth to either break up / burn up in our atmosphere or to hit the ground and leave an impact crater.
    c. We see meteors enter the atmosphere regularly and have evidence of recent impacts.
3. Mass is conserved during impacts. When a space rock hits the ground, it adds to the mass of the Earth.
4. Energy is conserved during impacts, but it can be transformed.

a. Though some of the kinetic energy from a meteor is transferred to other rocks upon impact (and these rocks are ejected into the air) most of the energy is transformed into heat.
b. The heat is enough to melt rock.
c. How much rock is melted (and blasted into the air) depends on the mass and the velocity of the space rock (because that's what determines kinetic energy).

The activities outlined in the learning segment table (the lesson sequence) ensure opportunity for your students to consider evidence for the ideas above. Your job is to pause on occasion and help them both note and record the ideas incrementally. Details can be found in the curricular resources, including the teacher slides (those with colored bands along the top/title margin) and the presenter notes found under student-facing slides.

We highly encourage you to record ideas beyond those that appear in the list above and to (as much as possible) follow your students' language around the ideas they feel are key. The curricular materials, in fact, ask you to (as a class) track *both questions raised and ideas developed* through two different representations. A rather complete sample of each such list is provided here. Your classroom lists will vary across periods as much as across years, so you will need to consider how you track ideas separately across your classes. (See the FAQ on the MBER website for tips.)

{next page shows the sample lists}

Sample List: What are we wondering? (You should have your own version.)
What happens to space rocks in impact craters?
What happens to the ground and to plants and animals when an impact occurs?
Are there other craters on Earth? What do they look like?
How likely would it be for a large meteor to hit the Earth now?
What really happens to matter during an impact?
What happens with energy and heat?
What makes a meteor vaporize or not vaporize if it actually makes it to the ground?

Sample List: What we've learned… (You should have your own version.)
There are lots of space rocks floating around the solar system.
Sometimes they enter our atmosphere and are visible as "shooting stars".
We see evidence that they have hit both Earth and other planets in the past.
Our atmosphere breaks up most space rocks that are headed toward Earth.
Minerals near impact craters sometimes show evidence of heat and pressure from the impact, even when the space rock itself is not found.
[If you explore some of the supplemental materials, you might also cover the following.]

> The last impact we know of was 200 years ago in the desert of the Arabian Peninsula.
> Older impact craters change with time and are often disguised by water, erosion (from wind and water) and by plants and ecosystems growing over them.
> Many meteors leave meteorites on the ground without leaving craters. (This is in part because they break up in the atmosphere and the pieces lose mass and velocity in the fragmentation and descent.)

Mass is conserved during (at least a) simulated impact.
Matter is conserved in the universe, so the matter in a real impact has to go *somewhere*.
In special circumstances, matter can be converted to energy ($E=mc^2$), but that's not what is happening during an impact. (We are pretty sure.)
The size and speed of a meteor affects what happens at impact and the size of the crater. The material the meteor and ground are made up of also affect the depth and width of the hole.
Energy comes in many forms and can be transformed or converted from one kind to another.

Kinetic energy is the energy of motion (and thus of meteors) and depends on the size (or mass) and speed of an object (like a space rock).
During impacts, most of the kinetic energy is converted to heat.
The heat from an impact is enough to melt rock.

(3) The "Rewind the Clock" Activity

As a means to building an initial model, students work in teams to think about what must have transpired to transform tiny pieces the nascent solar system (the dust and gas revolving around the sun as the solar disk) into a large planetary body. You review the class's criteria for models and then turn them loose on the driving question by asking them to create a representation for how Earth came to be in a series of three panels. (See materials for details.) In doing so, student teams develop initial models for Earth's formation, drawing upon what the class has learned so far. It's a moment of translating their understanding of impacts into a model that addresses the driving question.

After student groups have had an opportunity to examine others' models and to revise their own, you'll draw the class into a whole-group conversation to come to consensus on a first-draft model for Earth's formation. This is a key conversation that will require some planning. By the end of it, the class should have a relatively good consensus model that includes at least 6 of the 9 ideas listed below in the addendum.

Remember, *how the ideas are phrased and how long your list is* might vary depending on how ideas are combined. Only ideas 3, 4, and 9 are not simply consequences of ideas already developed. (See if you can develop ideas 1,2, 5, 6, 7, and 8 from the minimal version of the "What we've learned…" list outlined above. You should hopefully be able to track the connections.)

Addendum: The Model for Formation of the Earth
Addressing the question, "How did Earth's geosphere form?"

1. Earth formed when many small space rocks collided and came together.
2. When meteors (space rocks) combine, their masses add together.
3. Gravity increases when (1) the mass of an object increases and (2) the distance between objects decreases.
4. More gravitational attraction caused more collisions as the proto-Earth gained mass.
5. As more and more nearby space rocks collided with the forming Earth, the number of nearby space rocks decreased.
6. Collisions of space rocks (or space rocks with planets) convert kinetic energy into heat. More velocity or mass increases the kinetic energy and therefore the heat, at impact.
7. As proto-Earth was forming, there were so many collisions producing heat that the solid rocks melted into liquid (lava/magma).
8. The proto-Earth was a sphere of lava being constantly hit (and heated) by more space rocks.
9. As space rocks decreased in number, there were fewer collisions so the cold empty vacuum of space cooled proto-Earth down. The parts of Earth closest to the surface cooled down first, while the deepest center of earth remained molten rock.

Students may develop most components on this list during the “Rewind the Clock” activity and ensuing conversation, though the story-like nature depicted here will likely not show up until the class finalizes the model in the very last learning segment. Don’t worry if the initial model still feels a bit jumbled. Models in the classroom are meant to be “living documents”, meaning they are always subject to revision. Students will likely need some formal exploration of gravity and the process of cooling. Or they may not even recognize the import of some of the ideas (even those beyond gravity and cooling), which means you will need to problematize the “holes” in the model for them. (See a nudge outlined in the curricular teacher notes for some guidance on how to help the class evaluate the model, and be sure to check out the MBER Essential FAQ for tips on working with models—for example “Finalizing the Model”.) Gravity and cooling are addressed in the learning segments that follow “Rewind the Clock”. You will have opportunity to add these components and to edit them (and all other aspects of the model) when you develop a final model at the end of the unit.