SCAFFOLDS TO SUPPORT STUDENT LEARNING: JUDGING ASTRONOMICAL EXPLANATIONS

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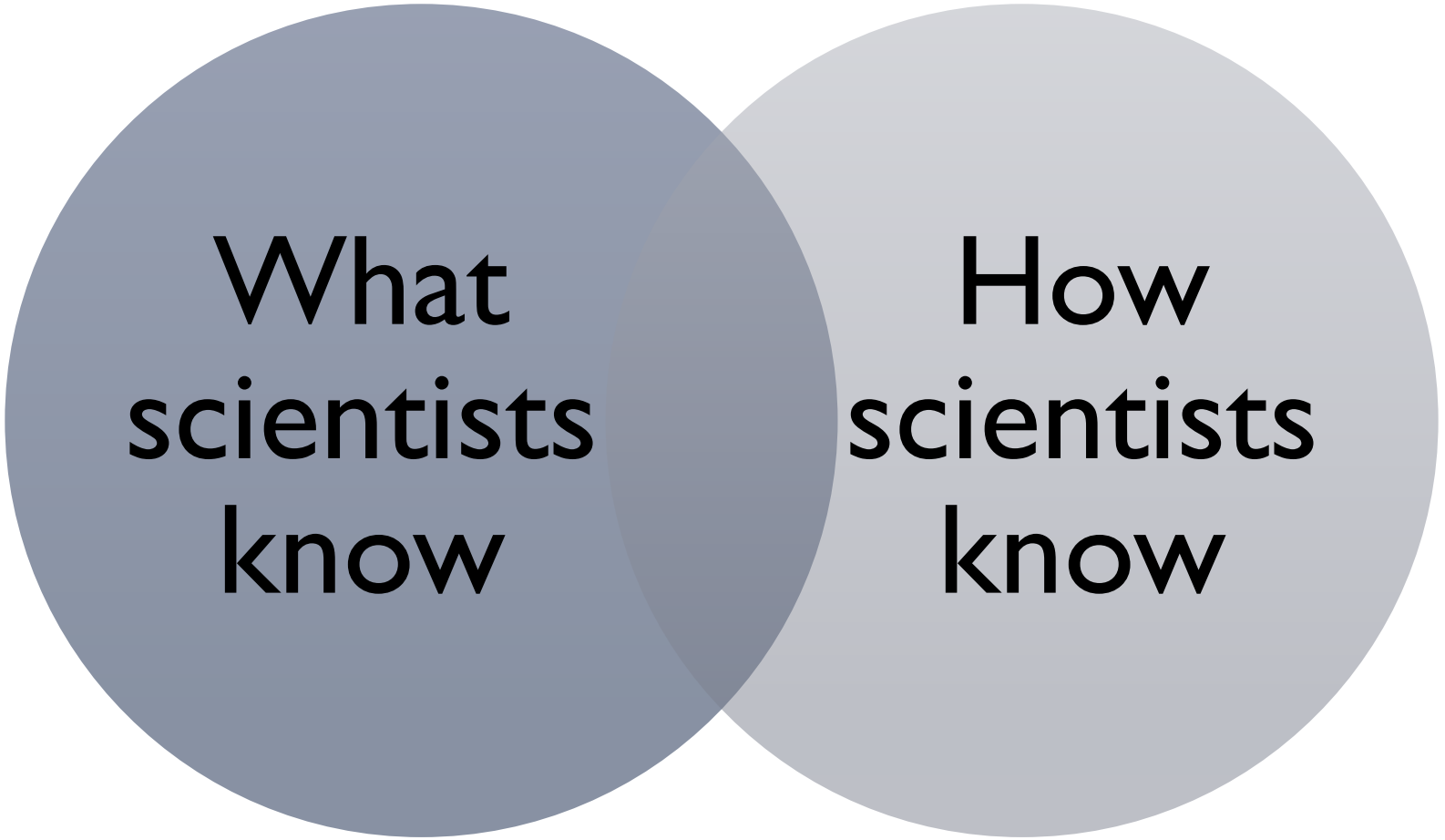
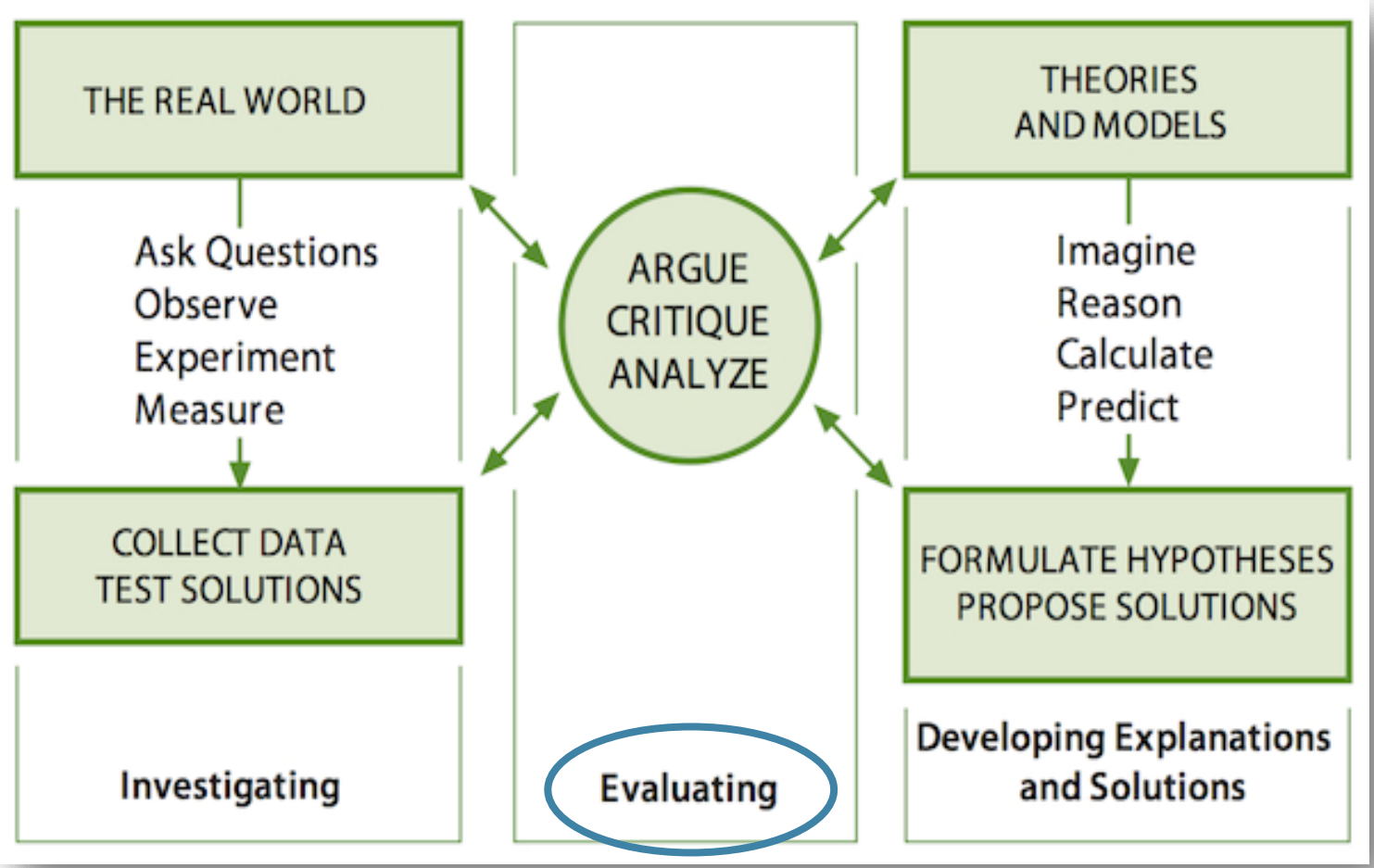
SCIENCE LITERACY



EVALUATION IN THE NGSS



- Evaluation plays a central role in the scientific practices as described by *A Framework for K-12 Science Education* (NRC, 2012) and subsequent Next Generation Science Standards (NGSS Lead States, 2013)

EVALUATION BEYOND THE NGSS

- Despite this, evaluation, scientific practices, and critical thinking skills may still be in development for college students

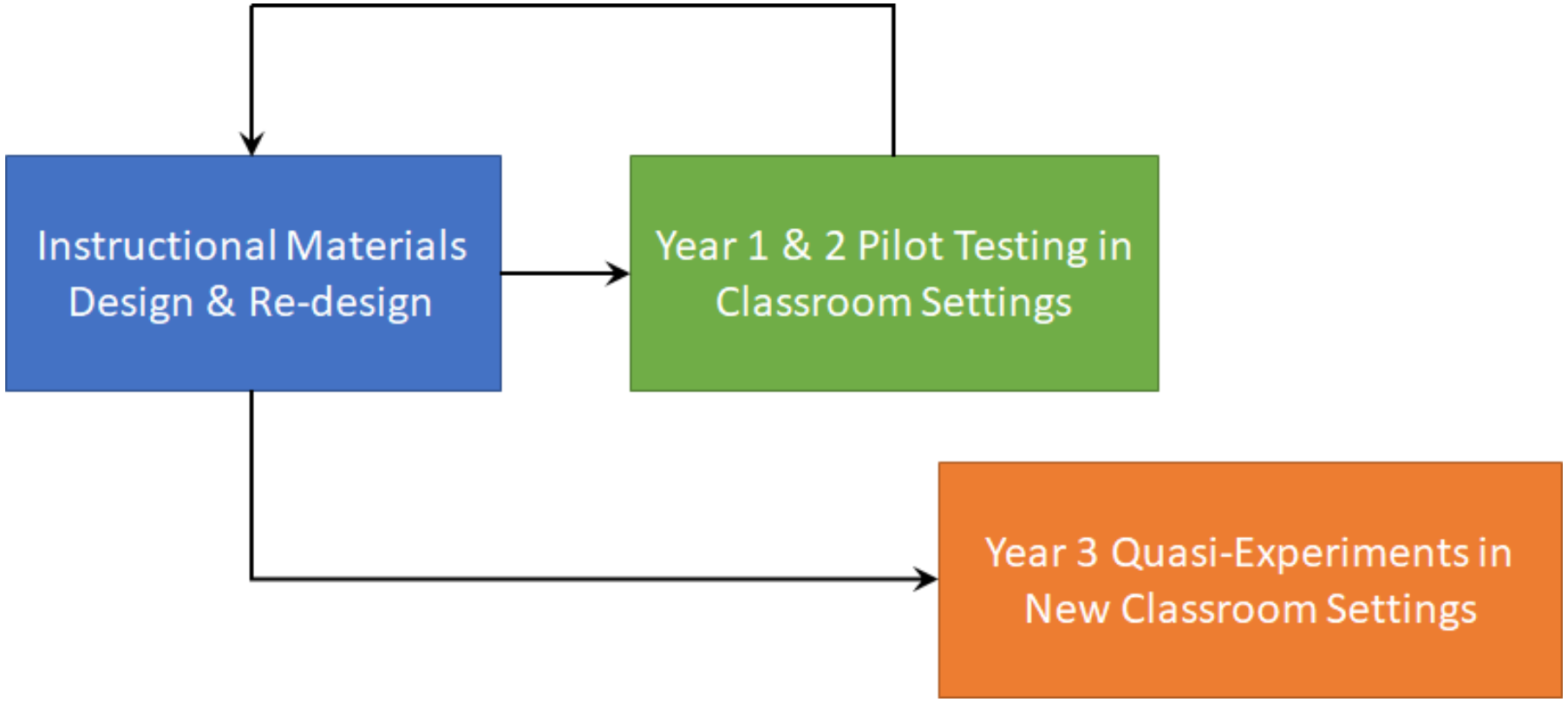
PLAUSIBILITY

- Students may find scientific explanations to be implausible
- Plausibility (and other) judgments about scientific explanations are often formed through automatic cognitive evaluations with little purposeful thinking
- Instructional scaffolds can help make students' evaluations explicit, thoughtful, and scientific (Chinn & colleagues, 2012, 2014)

THE MEL PROJECT—AN OVERVIEW

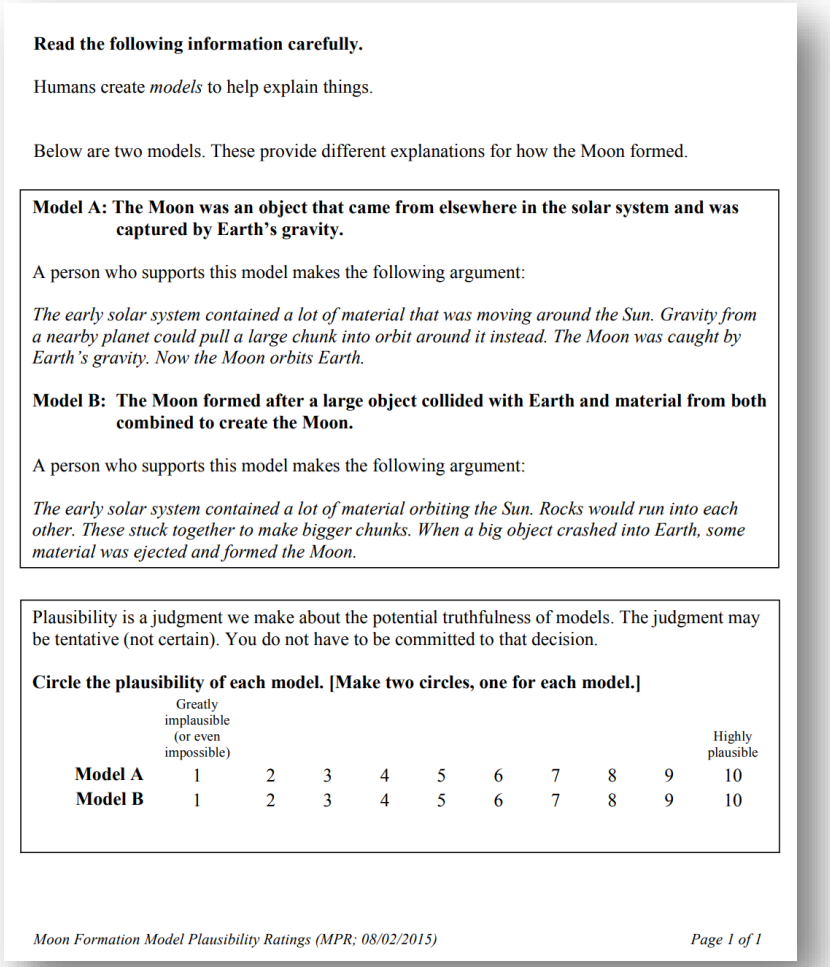
- Instructional materials (scaffold + supporting materials) development
  - Earth and space science
  - Secondary grades (6-12) but also can be used in teacher prep and introductory courses
  - Modular design
- Teacher professional development
- Research on student learning

SCHEMATIC OF THE MEL RESEARCH PROJECT



THE MOON MEL—MODEL PLAUSIBILITY RATINGS

- Students first read about and rate the plausibility of two models—here, capture and giant impact



Read the following information carefully.

Humans create *models* to help explain things.

Below are two models. These provide different explanations for how the Moon formed.

Model A: The Moon was an object that came from elsewhere in the solar system and was captured by Earth's gravity.

A person who supports this model makes the following argument:

The early solar system contained a lot of material that was moving around the Sun. Gravity from a nearby planet could pull a large chunk into orbit around it instead. The Moon was caught by Earth's gravity. Now the Moon orbits Earth.

Model B: The Moon formed after a large object collided with Earth and material from both combined to create the Moon.

A person who supports this model makes the following argument:

The early solar system contained a lot of material orbiting the Sun. Rocks would run into each other. These stuck together to make bigger chunks. When a big object crashed into Earth, some material was ejected and formed the Moon.

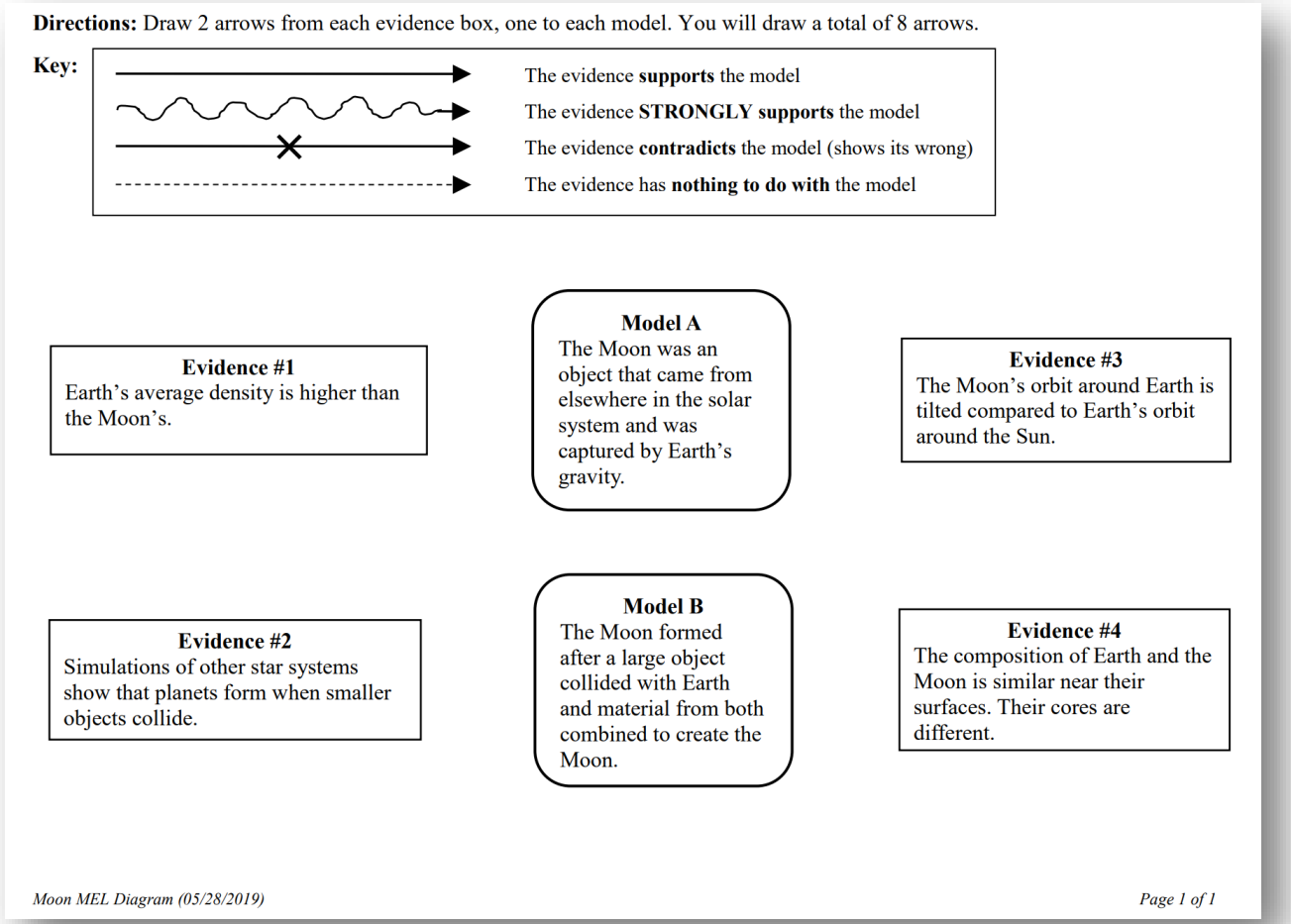
Plausibility is a judgment we make about the potential truthfulness of models. The judgment may be tentative (not certain). You do not have to be committed to that decision.

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

Moon Formation Model Plausibility Ratings (MPR; 08/02/2015) *Page 1 of 1*

THE MOON MEL



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
Earth's average density is higher than the Moon's.

Model A
The Moon was an object that came from elsewhere in the solar system and was captured by Earth's gravity.

Evidence #3
The Moon's orbit around Earth is tilted compared to Earth's orbit around the Sun.

Evidence #2
Simulations of other star systems show that planets form when smaller objects collide.

Model B
The Moon formed after a large object collided with Earth and material from both combined to create the Moon.

Evidence #4
The composition of Earth and the Moon is similar near their surfaces. Their cores are different.

Moon MEL Diagram (05/28/2019) *Page 1 of 1*

- The Model-Evidence Link (MEL) diagram is a graphical scaffold to facilitate students' critical evaluation of competing explanations of scientific phenomena

THE MOON MEL—EVIDENCE TEXTS

Evidence #1: Earth's average density is higher than the Moon's.

Earth has three main layers: the crust, the mantle, and the core. The core has two parts: the outer core and the inner core (Figure 1).

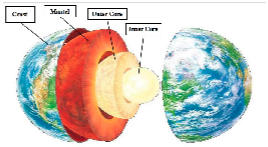


Figure 1: Artist's depiction of Earth's structure. Credit: Victoria Museum

Because each layer has a different composition, they also each have a different density. The average density of each layer is given in Table 1. The density is smaller than this average at the top of each layer and larger at the bottom.

Table 1. Density of Earth's layers.

Layer	Density
Crust	2.7 g/cm^3
Mantle	4.5 g/cm^3
Outer Core	11.1 g/cm^3
Inner Core	13.0 g/cm^3

Seismometers left on the Moon by Apollo astronauts suggest that the Moon also has three main layers: the crust, the mantle, and the core. We don't know the density of each of these layers, but the average density of the Moon is 3.3 g/cm^3. The average density of the Moon is close to the average density of Earth's crust and upper mantle, but much less than Earth's overall average density of 5.5 g/cm^3.

Evidence #2: Simulations of other star systems show that planets form when smaller objects collide.

Astronomers use computer simulations to determine how star systems (and our Solar System) formed. They then compare the simulations with observations of real objects to see how well they match.

Stars—and the planets around them—form out of giant clouds of gas and dust. Gravitational forces cause much of the gas to be pulled inward. At the center of the cloud this gas thickens and forms a star. Figure 1 shows how a forming system might appear.

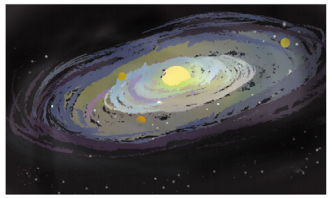


Figure 1: An artist's image of a star system during formation. Credit: Wright Seneres

Dust and other materials begin to collide as they orbit around the center of the cloud. Figure 2 shows these collisions over time. When they collide, these pieces fuse together because of the heat of the crash, forming larger chunks. This a little like how individual snowflakes can come together to make a snowball. As the chunks get bigger, they have even more collisions. The smaller pieces collide with and stick to larger chunks. These chunks of material will continue to combine and form even bigger objects. After many collisions (too many to count!), a planet and other bodies will have formed.

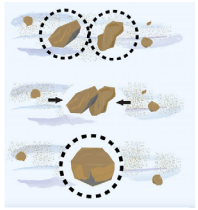


Figure 2: Clumps of rock join together during planet formation. Credit: Wright Seneres

Evidence #3: The Moon's orbit around Earth is tilted compared to Earth's orbit around the Sun.

The path of an object in the Solar System as it orbits the Sun makes a plane. For Earth's orbit, this is called the ecliptic.

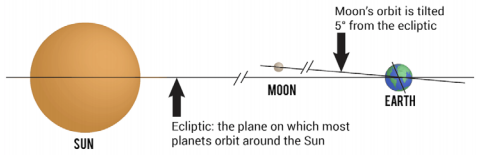


Figure 1: The Moon's orbital plane compared to Earth's orbital plane as viewed from the side. The figure is not to scale; parallel lines on the orbits (//) indicate breaks in the distance. The line through Earth indicates its rotational axis. Credit: Wright Seneres

The Moon's orbit around Earth also makes a plane. But, this plane is tilted about 5° from the ecliptic. This means that sometimes the Moon is a little above the ecliptic and other times it is a little below the ecliptic. Figure 1 shows the ecliptic and the tilt of the Moon's orbital plane.

If the Moon formed at the same time as Earth, it probably would have an orbit that is closer to the ecliptic. Its tilt may be related to a collision.

Evidence #4: The composition of Earth and the Moon is similar near their surfaces. Their cores are different.

Geologists study the composition of Earth and the Moon. By studying rock samples and seismology, they can estimate the percentage of different elements present. There are many of the same types of elements present on both Earth and the Moon, but in different amounts depending on where you look. Table 1 lists the percentage by mass of four major elements near the surface of each body (crust and upper mantle).

Table 1. Composition (percentage by mass) of Earth and the Moon near their surfaces (crust and upper mantle).

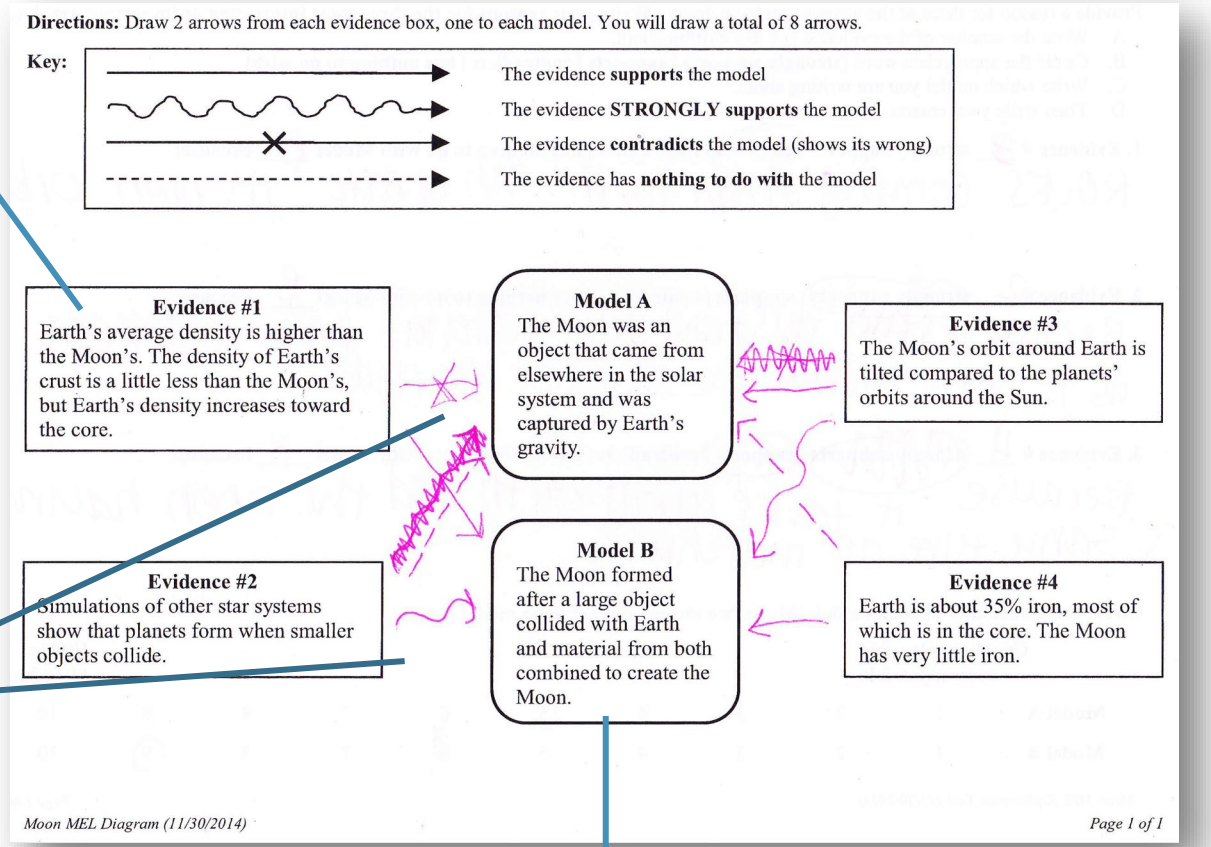
Element	Earth	Moon
Oxygen	44.4%	43.6%
Magnesium	23.0%	19.5%
Silicon	21.3%	21.7%
Iron	6.4%	9.3%

Earth's inner core contains mostly solid iron. The outer core is mostly liquid iron and about 10% other elements like magnesium and sulfur. This means that overall, Earth is about 35% iron. Geologists dono't know as much about the Moon's interior composition. They think it is about 1-2% iron in the core.

THE MOON MEL

- Students evaluate the connection between four different lines of evidence and the two models

Evidence statements, with separate elaboration

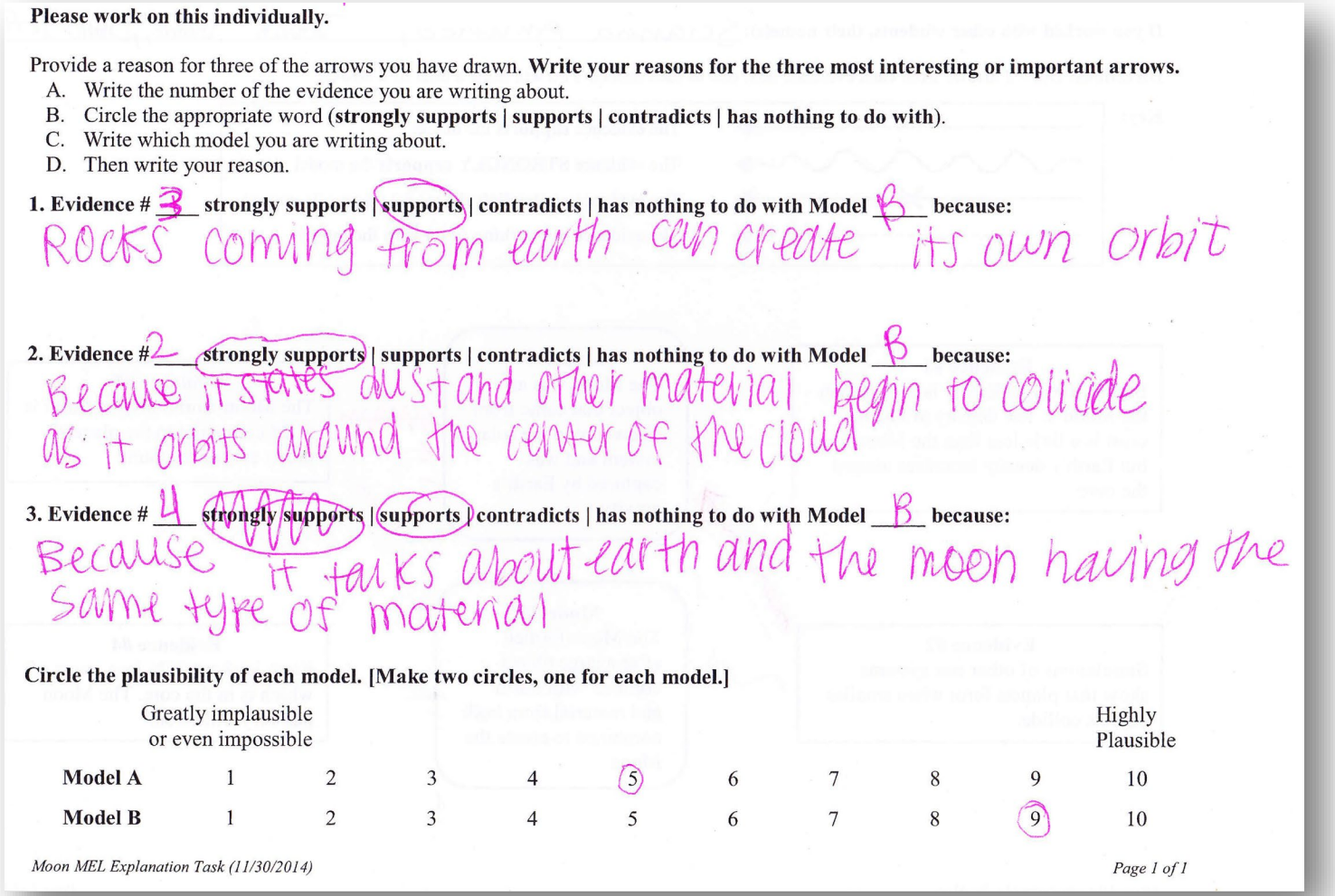


Students draw arrows to connect evidence to model

Two explanatory models, A and B

THE MOON MEL—EXPLANATION TASK

- The Explanation Task requires students to elaborate on the connections they draw and (re)rate the plausibility of the two models



Please work on this individually.

Provide a reason for three of the arrows you have drawn. **Write your reasons for the three most interesting or important arrows.**

A. Write the number of the evidence you are writing about.
B. Circle the appropriate word (**strongly supports | supports | contradicts | has nothing to do with**).
C. Write which model you are writing about.
D. Then write your reason.

1. Evidence # 3 **strongly supports | supports | contradicts | has nothing to do with Model** B **because:**

ROCKS coming from earth can create its own orbit

2. Evidence # 2 **strongly supports | supports | contradicts | has nothing to do with Model** B **because:**

Because it states dust and other material begin to collide as it orbits around the center of the cloud

3. Evidence # 4 **strongly supports | supports | contradicts | has nothing to do with Model** B **because:**

Because it talks about earth and the moon having the same type of material

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

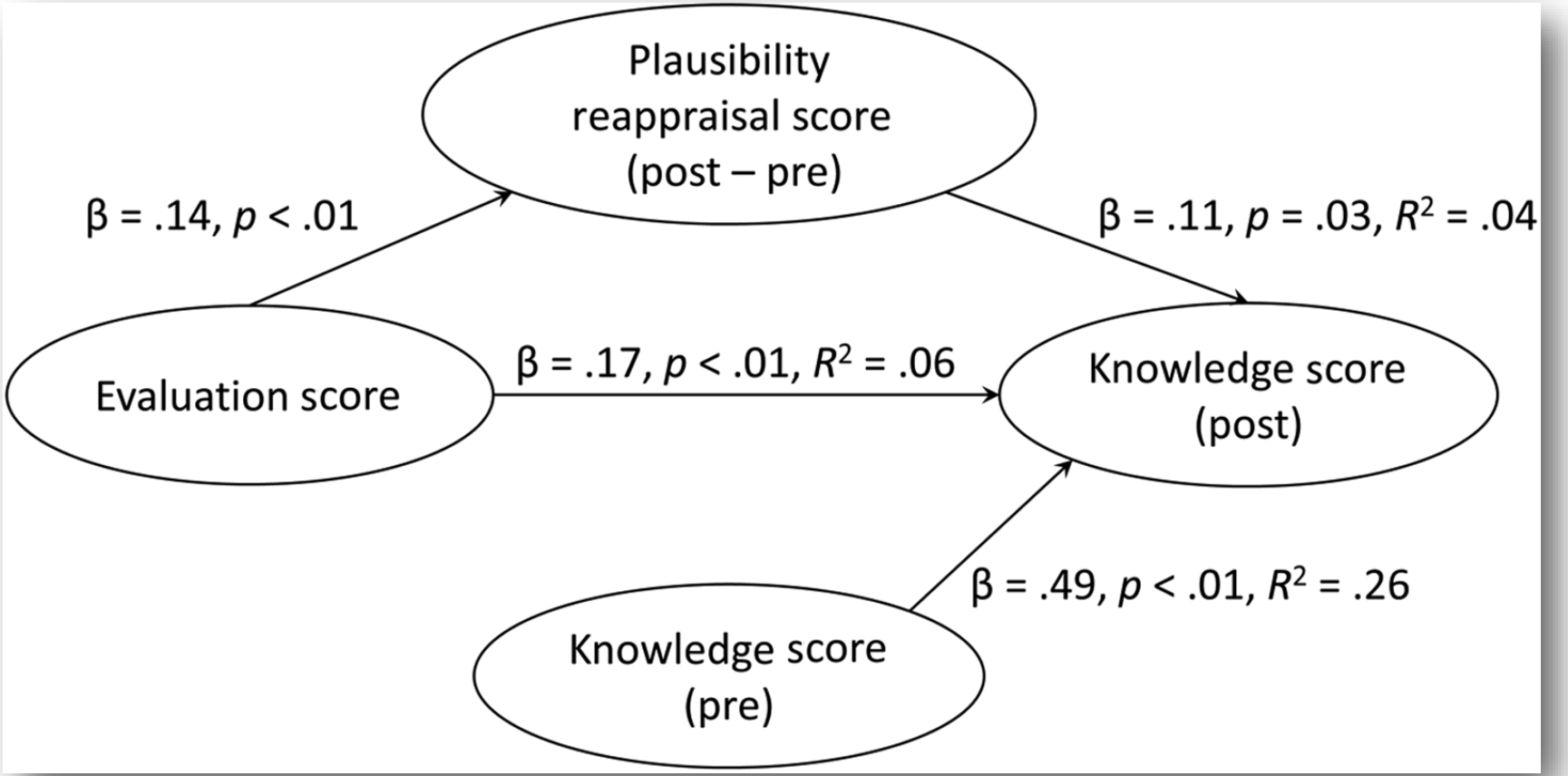
	Greatly implausible or even impossible									Highly Plausible
Model A	1	2	3	4	(5)	6	7	8	9	10
Model B	1	2	3	4	5	6	7	8	(9)	10

Moon MEL Explanation Task (11/30/2014) *Page 1 of 1*

RESEARCH RESULTS (MULTIPLE MEL TOPICS)

LOMBARDI ET AL. 2018 SCIENCE EDUCATION

- Knowledge scores show greater increase with higher evaluation scores, mediated by plausibility reappraisals



MEL > MEL2

- Improvement in knowledge scores
- Better than comparison activities (Lombardi et al. 2018 *Contemporary Educational Psychology*)

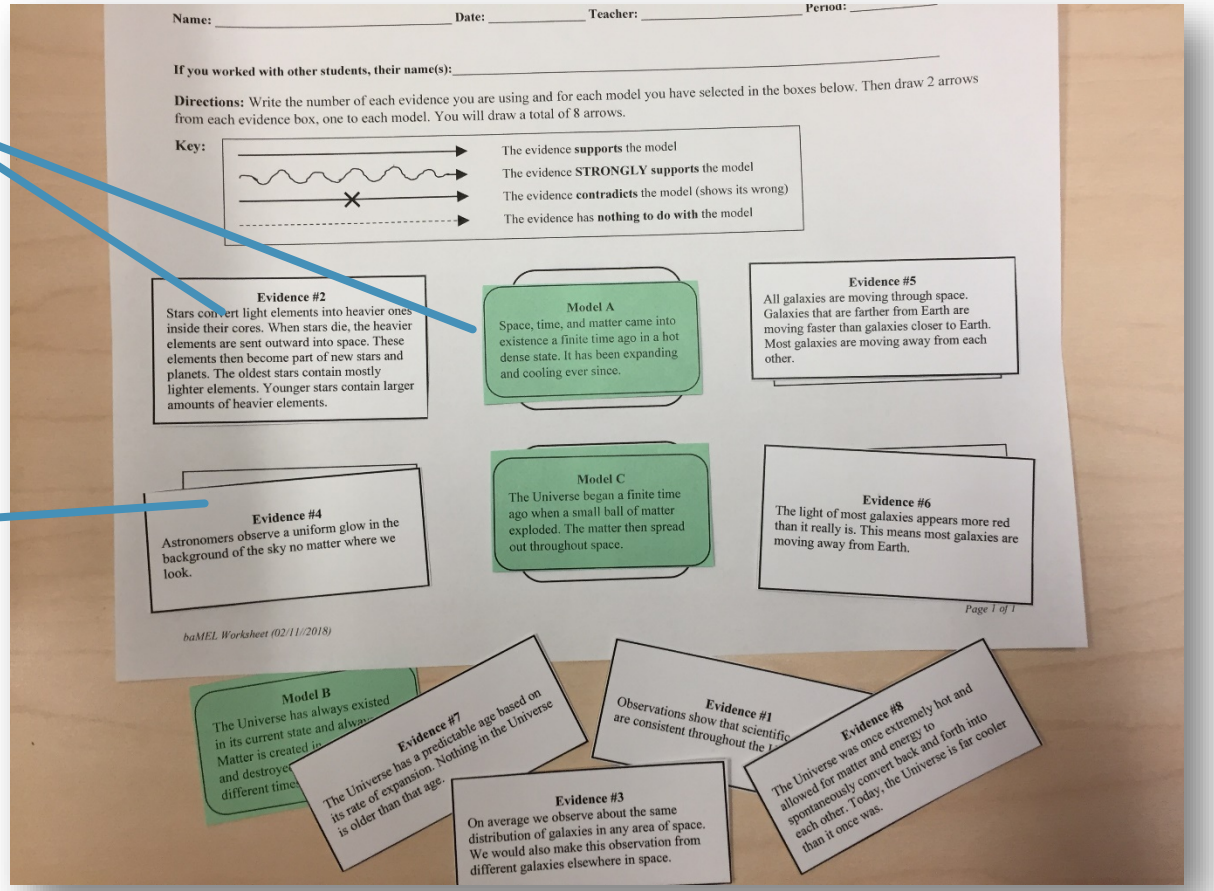
- *Not where we wanted it to be*

- Increase students' agency while using the scaffold
- Build-a-MEL

MEL2—THE ORIGINS OF THE UNIVERSE BUILD-A-MEL

Students select from 3 models, 8 lines of evidence

Create own MEL then proceed as before



THE ORIGINS OF THE UNIVERSE BUILD-A-MEL

Model	Statement
Model A	Space, time, and matter came into existence a finite time ago in a hot dense state. It has been expanding and cooling ever since.
Model B	The Universe has always existed in its current state and always will. Matter is created in some places and destroyed in other places at different times.
Model C	The Universe began a finite time ago when a small ball of matter exploded. The matter then spread out throughout space.

MEL2 RESULTS TO DATE

- Near end of Year 3 of 4(?)
- Knowledge increases greater than with the pre-constructed MEL activities
- Shifts in engagement over time
- *…Data collection and analysis is ongoing!*

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THANK YOU!

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