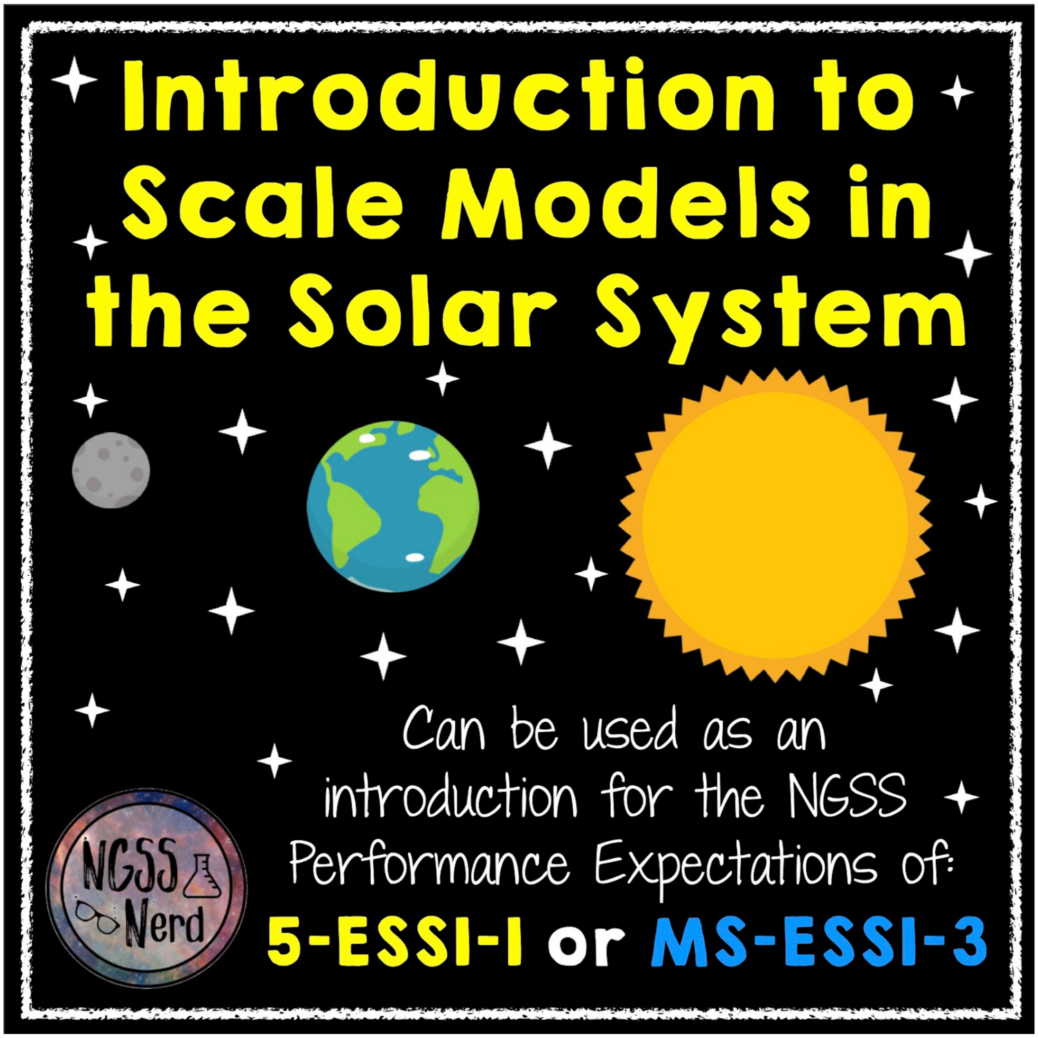
Analysis of a Science Learning Design & Assessment Plan:

Introduction to Scale Models in the Solar System



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EDUC 398: Curriculum & Instruction in Math and Science Using ADST

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May 27, 2022

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Does it satisfy the requirements of our BC Curriculum?

The learning design and assessment plan we have chosen to analyze, "Introduction to Scale Models in the Solar System", is a *Teachers Pay Teachers (TpT)* resource. As such, you have likely deduced our main criticism: that it is not explicitly tailored to British Columbia's curriculum. Julia Cannon (a.k.a. "NGSS Nerd" and creator of this resource) is, like most TpT publishers, an American-based educator with an American lens and American learning objectives. In her "Teacher's Guide" (p. 2), Cannon clearly articulates that this learning design—the first in her "5th grade Space Systems bundle"—is intended to satisfy American curricula, particularly those State curriculums that have adopted the Next Generation Science Standards (NGSS). Cannon highlights two NGSS Standards: 5-ESS1-1, which requires that students be able to "support an argument that the apparent brightness of the sun and stars is due to their relative distance from the Earth", and MS-ESS1-3, which states that students should be able to "analyze and interpret data to determine scale properties of objects in the solar system" (p. 2). BC's Curriculum no longer focuses on performance standards, but rather Big Ideas, Curricular Competencies, and Content (2016). Furthermore, looking at BC's Science Curriculum, we do not see the mention of Space, the solar system, or scale in Grade 5. So, what does this mean for us, as BC educators? Do we throw Cannon's learning design to the wayside simply because it originated in a different country, with a different curriculum in mind? Or can we adapt this lesson and utilize it effectively in a British Columbian context? We argue that, yes, we can, and we do so for several reasons.

First, the learning design addresses one of the Big Ideas in our Grade 6 curriculum: that "the solar system is part of the Milky Way, which is one of billions of galaxies" (2016). In addition, the lesson helps students seek answers to one of our Big Idea Elaborations, specifically "what are the relationships between Earth and the rest of the universe?" (2016). Second, it speaks to, and supports, several of the Grade 6 Curricular Competencies for Science, including those outlined explicitly in the following sections: *Questioning and predicting* (demonstrate a sustained curiosity about a scientific topic or problem; make observations in familiar and unfamiliar contexts; and make predictions about the findings of inquiry); *Planning and conducting* (observe, measure, and record data, using appropriate tools); *Processing and analyzing data and information* (identify patterns and connections in data; compare data with predictions and develop explanations for results; and demonstrate an openness to new ideas and consideration of alternatives); *Evaluating* (demonstrate an understanding and appreciation of evidence); *Applying and innovating* (cooperatively design projects; transfer and apply learning to new situations; and generate and introduce new or refined ideas when problem solving); and *Communicating* (communicate ideas, explanations, and processes in a variety of ways). Third, it addresses two Content areas for Grade 6 Science: “the overall scale, structure, and age of the universe” and “the position, motion, and components of our solar system in our galaxy” (2016). Fourth, the lesson lends itself to cross-curricular learning, specifically Science with Mathematics, as well as to inquiry-based pedagogy, diversity, and inclusion (which are the topics of the next two sections).

Will it promote inquiry-based pedagogy in our Science classrooms?

During our intensive week in Prince George, we were fortunate to hear from three UNBC faculty members as they shared their thoughts on inquiry-based learning. Instructor Bonnie Fuller explained her thinking, that “all Math and Science are interconnected, and that teaching with ADST and an experiential-based approach brings relevance to our students’ learning by making them aware of interconnections” (Fuller, Lecture Notes). She further pointed out the usefulness of creating and following models, which is a key component of Cannon’s learning design. Second, Dr. Dan Ryan approached inquiry-based learning from the angle of Applied Statistics, posing the question: “How strong is the evidence for the question you’re looking at?”, and emphasizing the process of hypothesis testing (positing a null hypothesis, collecting evidence and presenting it in an open and impartial manner, weighing the evidence, and then reconsidering the initial hypothesis in light of the evidence)

(Ryan, Lecture Notes). Third, Dr. Hart Banack noted that "teaching and research are journeys, requir[ing] a spirit of adventure." He explained the underlying assumption of all research/inquiry: that "meaning exists and patterns can be intentionally investigated to help understand future situations." He reiterated that, to engage in research, "the problem needs to be articulated and/or defined" (Banack, Lecture Notes).

Cannon's lesson utilizes a guided learning progression to help learners think about the concept of scale by exploring the scale of size and of distance. Learners "start by reflecting on how large the Moon and Sun look from Earth" by engaging in a "Think about it" written reflection, which allows the teacher to assess students' prior knowledge. Alternatively, we believe that students could participate in a Think-Pair-Share activity, where they would then contribute their reflections to a class-wide tally chart. In this way, the teacher would be able to formally access students' prior knowledge in a quick and interactive way. Next, learners are guided to create an initial scaled model of the Earth, Moon, and Sun; this is done to compare their sizes, noting that it is necessary to create a scaled model since these objects are much too large to model as life-size. In the video that accompanies the lesson, Cannon notes that the model the class will create is six billion times smaller than life-size – a fact that appeals to target students. Third, learners create a scaled model together, as a class, that shows the scaled distance of the Earth, Moon, and Sun, along with their scaled sizes. This learning activity requires a large area (either outside or in a gymnasium or hallway) to ensure enough space to represent the distance of the Sun from the Earth (21m in this model). Here, the teacher would have an opportunity to observe and informally access students' ability to expand upon earlier thoughts and ideas.

We believe that Cannon's learning progression will guide learners successfully as it clearly conceptualizes the idea of scale (based on size), and scaffolds upon the idea to incorporate the scale of distance. In her model, the Earth is 2mm in diameter, the Moon is 0.5 mm in diameter and the Sun is 19.8 cm in diameter. Along the progression, Cannon continues to activate prior knowledge, incorporating math concepts, and making and reflecting on predictions (metacognition). Cannon provides explicit instruction on the distances of the Earth to the Moon, and the Earth to the Sun (p. 4), while students take notes in the form of a Cloze exercise. The lesson then poses a clear question for inquiry, based on what the students have learned: "If the Earth and Moon are this far apart [5.5 cm], how far would our 19.8cm Sun be from the Earth?" Learners are invited to participate in the whole-group activity, physically making a prediction/hypothesis of the relative distance of the Sun from the Earth by placing themselves where they predict the Sun would be. The teacher then helps them check their hypothesis by stretching out a 21-meter-long piece of yarn to show how far the Sun would be in the model. Following the whole-group modeling activity, students use what they have learned about scale models to answer questions on a worksheet. Here, they can articulate their predictions, which solidifies the learning intention (this could be done orally, with a partner for younger students or those who struggle with written output).

The article, "Predict, Observe, Explain (POE)," by Chris Joyce, points out that "unless students are asked to predict first what will happen they may not observe carefully"; furthermore, "writing down their prediction motivates them to want to know the answer" (p. 1). This practice fits with Dr. Banack's emphasis on questions needing to be clearly defined. Joyce's article also points out that "events that surprise create conditions where students may be ready to start re-examining their personal theories" (p. 1). In this lesson, the model of the scale of distance between the Earth and Sun is a fun surprise element. Many models that we see of the solar system are understandably not to scale, which influences students' predictions, so it is advantageous for students to have the chance to work with a true-to-scale model. Overall, then, we believe that this modeling activity promotes inquiry-based pedagogy and provides an opportunity for learners to begin exploring the strengths and weaknesses of scale models (and for the teacher to informally assess the early learning of this concept).

Does it adhere to the principles of diversity, equity, and inclusion, and to the FPPL?

Diversity, equity, and inclusion act as guides to maintain and ensure that the learning environment is equipped for all types of learners. This is important because it reduces fear in the classroom, allows learners to take more risks, and improves student skills and performance. In turn, this leads to a variety of perspectives, fosters creativity, and sparks a positive and nurturing classroom. As a cohort, we have come to understand the significance of background knowledge and how it enables students to make connections to present and future learning. Not only does it prepare students for new concepts, but it also allows them to recognize that their culture of learning and experiences are valued and encouraged.

Throughout Cannon's lesson, students are expected to reflect upon their prior knowledge. For example, students begin reflective practice regarding how large the Moon and Sun appear from the Earth, and reflect about prior math concepts including rounding, place value, and ordering to enhance the process of creating a scaled model. All learners are addressed in the learning design because it acknowledges that each student brings merit to the learning environment, leading to cooperation, respect, appreciation, and reciprocity. Additionally, addressing background knowledge and having students use it in the lesson will help students better understand the content, and make the learning experience richer. According to Marzano (2004), "[a]lthough it is true that the extent to which students will learn this new content is dependent on factors such as the skill of the teacher, the interest of the student, and the complexity of the content, the research literature supports one compelling fact: what students already know about the content is one of the strongest indicators of how well they will learn new information relative to the content" (p. 1). By placing value on each individual student, including where they are currently situated in their learning, Cannon has excelled.

As teacher candidates and future educators, we also recognize the importance of the First Peoples Principles of Learning, and the inspiration that these concepts place on the heart, mind, and souls of our students. Cannon's learning design adheres to the principle in First Peoples' culture that recognizes learning as holistic, reflexive, reflective, experiential, and relational. This learning design allows students to take what they have learned on paper and transform it to reality (i.e., by developing their own scale models in the Solar System). Having students bring their materials to a larger area, such as the gymnasium, hallway or outdoors, gives students the opportunity to learn together in a new space, and such experiential learning is significant. According to Kao, Liu, and Huang (2014):

> Studies have found that Indigenous students prefer group activities and learning through hands-on experience. Therefore, curriculum design should emphasize group activities and encourage students to engage in group discussions. In terms of "acquisition," the history and culture of ethnic groups should be included in courses for Indigenous students, and new scientific concepts should be introduced using their daily life experiences (p. 9).

Cannon has maximized learning for students by stimulating the learning environment and creating a larger, more comfortable, visual space.

Upon analysis, we hope that you, like us, find merit in this learning design and assessment plan. We should not throw Cannon's lesson to the wayside simply because it originated in a different country, with a different curriculum. We believe that Cannon's learning design can be adapted and utilized effectively in our classrooms here in British Columbia.

References

Banack, Hart. (2022). Lecture on*, "Teachers, Teaching and Learning and Research."* Personal collection of H. Banack. School of Education, University of Northern British Columbia, Prince George, BC.

BC's Curriculum. (2016). Building Student Success: Science, Grade 6. *Ministry of Education*, *Province of British Columbia*. https://curriculum.gov.bc.ca/curriculum/science/6/core

Cannon, Julia. (2016). "Introduction to Scale Models in the Solar System." *Teachers Pay Teachers*. Retrieved May 20, 2022 from https://www.teacherspayteachers.com/FreeDownload/NGSS-Freebie-Introduction-to-Scale-Models-in-the-Solar-System-3717387

Fuller, Bonnie. (2022). Lecture on, *"Teaching Math & Science*." Personal collection of B. Fuller. School of Education, University of Northern British Columbia, Prince George, BC.

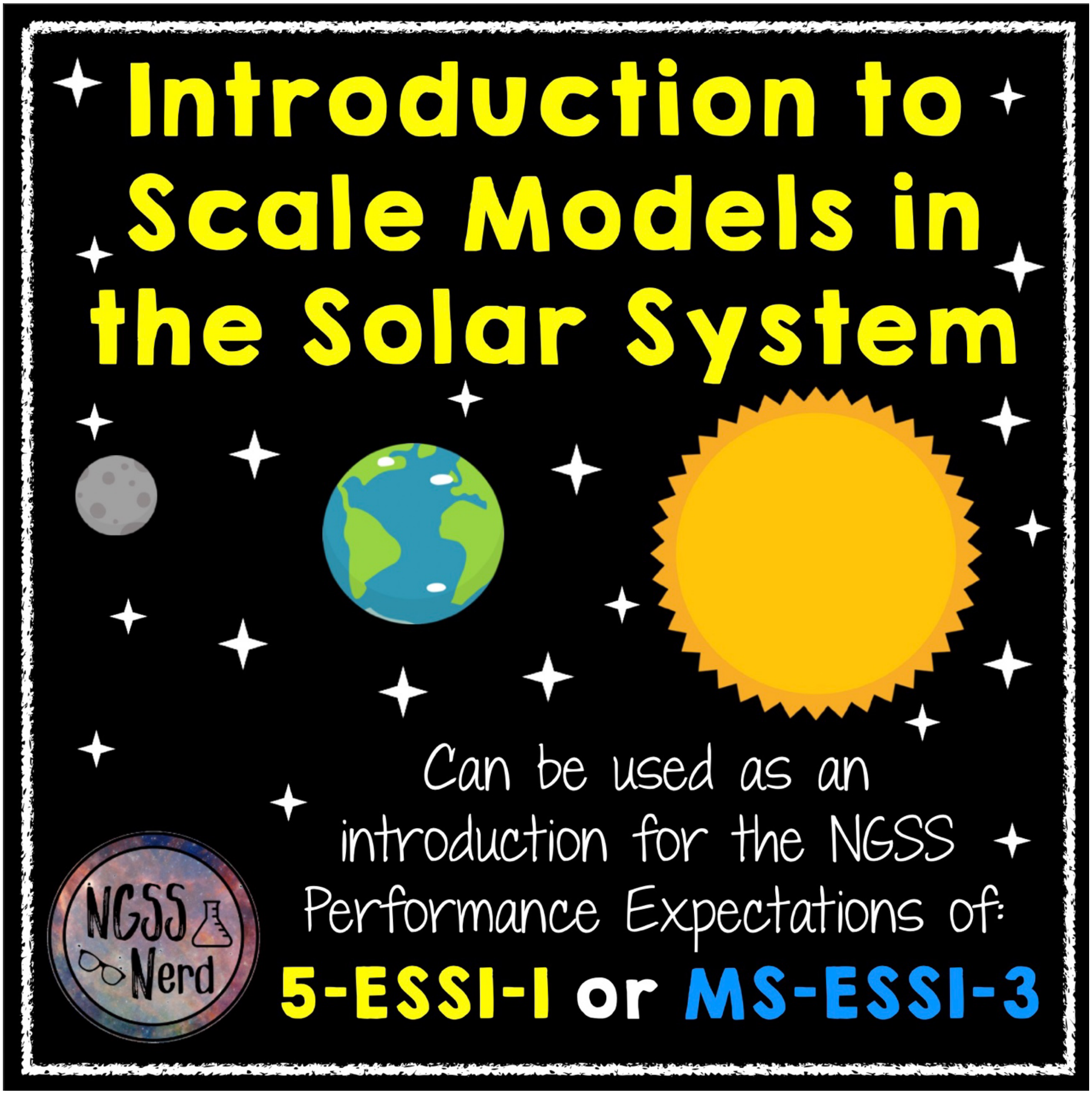
Joyce, Chris. (2006). Predict, Observe, Explain (POE). *New Zealand Council for Educational Research*. Retrieved May 23, 2022 from https://arbs.nzcer.org.nz/predict-observe-explain-poe

Kao, M. W., Liu, Y. C., & Huang, T. (2014). Establishment and Evaluation of Science Curriculum Development Principles for Taiwan Indigenous Peoples. SSRN 2463208.

Marzano, R.J. (2004). Building background knowledge for academic achievement: Research on what works in schools*.* Ascd.

NGSS. (2020). "The Standards." *Next Generation Science Standards: For States by States.* https://www.nextgenscience.org/search-standards

Ryan, Dan. (2022). Lecture on, "*Applied Statistics."* Personal collection of D. Ryan. School of Education, University of Northern British Columbia, Prince George, BC.



https://www.teacherspayteachers.com/FreeDownload/NGSS-Freebie-Introduction-to-Scale-Models-in-the-Solar-System-3717387

Teacher Guide

Overview of Resource	This freebie is the first lesson in my 5th grade Space Systems Bundle, and leads up to the NGSS Standard of **5-ESS1-1. Support an argument that the apparent brightness of the sun and stars is due to their relative distances from the Earth.** It can also be used as an introduction to **MS-ESS1-3. Analyze and interpret data to determine scale properties of objects in the solar system**. In this lesson, students will be introduced to the concept of scale using the Earth, Moon, and Sun. They will eventually apply their knowledge of scale to the distance and brightness of stars (5th grade) or more objects from our solar system (Middle School). Students start by reflecting on how large the Moon and Sun look from Earth. They then compare this observation to their actual sizes, by looking at data and creating a scaled model. Students see that the Sun is many times larger than the Moon, even though they look about the same size from Earth. Students then look at the scaled distance of the Earth, Moon, and Sun to see that the Moon is much closer to the Earth than the Sun is. Lastly, students reflect and answer questions about the scale of the Sun, Moon, and Earth models that they created.
Lesson Objective(s)	• **Students will create a scale model of the Earth, Moon, and Sun to compare their sizes and distances from each other.**
NGSS Alignment	**Additional NGSS Aligned Info:** **NGSS Science & Engineering Processes:** • Modeling: Students will create two models of the Earth, Moon, and Sun to compare their sizes and distances away from each other. **NGSS Cross-Cutting Concepts:** • Scale: Students start to explore the concept of scale in this lesson by comparing scaled sizes of the Earth, Moon, and Sun, and then contrasting that with how large each object appears in the sky from Earth.
Materials / Prep	**Watch this video** for directions to set up each of the models from this lesson. For the second model, find a space that is at least 70 feet (21 meters) long, such as a hallway or gym. Print out the teacher copy of the model at the end of these directions. You may also want to have a long measuring tape or piece of yarn (at least 70 feet). If you can't set up the model, you can use the end portion of the video above to show to students instead. Each student needs: • Student Worksheets • A Ruler • A sharp pencil or pen with a fine tip - mechanical pencils are great! • *Optional: Compasses to draw the Sun*

Lesson Details	**Introduction Text (page 1):** Read about the "Size and Distance of Space Objects" as a class. Ask students to complete the "Think About It" question at the bottom of page 1. Students may have slightly different answers, but they should say that the Moon and the Sun look like they are about the same size from Earth, or possibly that appearance of one is a little bit bigger than the other. They should not say that one looks way larger than the other at this point. **Actual Sizes (page 2):** Give students notes about the diameters of the Earth, Moon, and Sun. Ask students to fill in the table in using the information from the table above. You could review math concepts at this section, like rounding, place value, or ordering values if you want to. Students will reflect on whether the sizes of the Earth, Moon, and Sun matched their expectations. Introduce the idea of scale models by reading together. **Scale Model of Size (Page 3)**: On this page, students will draw the scaled sizes of the Earth, Moon, and Sun. Click here to **watch the video** of how to instruct students to set this up. **Scale Model of Size and Distance (Page 4):** Tell students that you've looked at the size of each object, but now you also want to consider how close or far away they are from each other. It's important to emphasize that in the first model only the size was correct. In the second model, you will include a scale model with correct size AND distance. Give notes for the distances of the Earth to the Moon, and the Earth to the Sun. Ask students to look at the information you gave them and complete the fill in the blank sentence about the distances. Next, tell students that if the Earth and Moon were actually the size of the models they created on page 3, that they would be 5.5cm away from each other. Instruct students to follow the directions to draw the scaled model of the Earth and Moon. Ask students to then predict, "If the Earth and Moon are this far away, how far would our 19.8cm Sun be from the Earth?". You should not fill in any information about how far the Sun actually would be in the model at this point. Tell students to bring their papers and pencils out to the larger location that you have designated for the lesson (or you can play the **end of the video** if larger spaces are unavailable at your building). Show students that the model you have has the Earth and the Moon 5.5cm away. Ask students to walk to where they predict the Sun would be. After students predict, start walking backwards until you get to 70 feet, and place the Sun there. Ask students to record observations at the bottom of page 4. **Analysis of Scale Models (Pages 5-6)**: Return to the classroom and lead the students in a discussion about the models using the questions on pages 5 and 6. You can either have the students answer the questions ahead of time and then review together, or answer them as you discuss. Page 5 should be completed by everyone. Page 6 has more advanced questions, and can be completed by everyone or included as advanced work for some learners.

TEACHER COPY OF EARTH, MOON, SUN SCALE MODEL

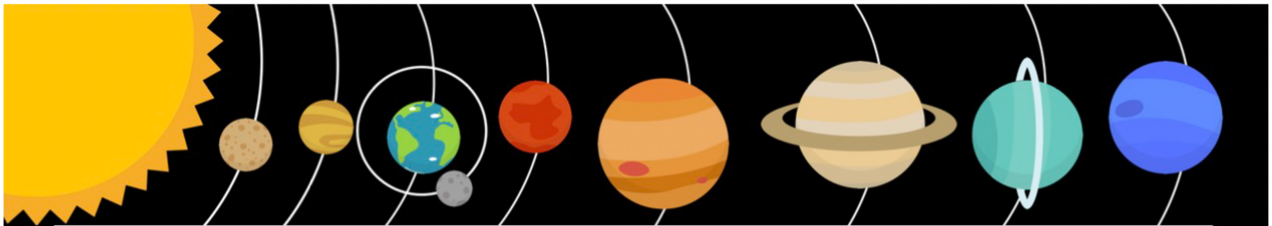
DIRECTIONS:

1. Cut out each of the parts on the dotted lines below.
2. Go to a location that has a distance of at least 70 feet (hallway, gym, playground).
3. Lay down the first strip of paper that shows the Earth and Moon sizes and distance. Remind students that this is what they drew in their notebooks. Put the “Earth” label pointing to the small circle, and the “Moon” label pointing to the dot.
4. Next, ask students to go where they predict the Sun would be.
5. After students have made their prediction, take the cutout Sun to 21 meters (70 feet) away from the Earth.
6. Ask students to come back near the Earth, and write their observations about the model at the bottom of their paper.

EARTH →

MOON →

SUN



HOW BIG AND FAR AWAY ARE OBJECTS IN SPACE?

Name: ______________________
Date: ______________________

Objective: I will create a scale model of the Earth, Moon, and Sun to compare their sizes and distances from each other.

The Size and Distance of Space Objects:

The **universe** is everything that exists, including all of space. The planets, moons, stars, and the Earth are all part of the universe. It is incredibly difficult for us to picture how big the universe is, because it is immensely huge. The Earth is very small compared to some objects in space, yet the Earth seems HUGE to us. It is also difficult for us to imagine how far apart objects in space are from each other, because the distances are much farther than anything we travel on Earth.

Today, we'll focus on comparing the sizes and distances of three space objects that you are probably the most familiar with: The Sun, Moon, and Earth.

Think about it:
When you are standing on the Earth and look up into the sky, how do the sizes of the Moon and Sun compare? Does one look bigger than the other, or do they look about the same size?

____
____
____
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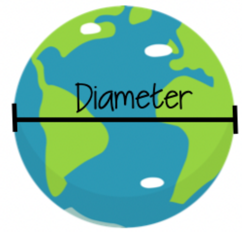
ACTUAL SIZES

The Earth is ______________ kilometers (km) wide. The width of a sphere is also called its **diameter**. The Moon has a diameter of ________________ km. The Sun has a diameter of _____________km.



DIRECTIONS: Using the information above, put the Earth, Moon, and Sun in order from smallest to largest, and include their diameters in the table:

	Smallest	Middle	Largest
Object			
Diameter (km)			

Is this order (from smallest to largest) what you expected it to be, or are you surprised?

____
____
____

SCALE MODELS

If we want to compare the sizes of the Earth, Moon, and Sun, we cannot draw them in their actual size. They would be WAY too big to draw! These objects are immensely large and far away from each other.

We need to draw a **scale model**. A scale model is either a zoomed in representation of something that is very small, or zoomed out version of something that is very large. To make a scale model you either shrink or enlarge all of the objects by the same amount.

On the next page, we are going to draw a scale model of the size of the Earth, Moon, and Sun.

Scale Model of Size

Draw a scale model of the Moon, Earth, and Sun that shows their sizes compared to each other. If we zoom out to draw these huge objects about six billion times smaller than they actually are, they would be the following sizes:

Earth: 2 mm	**Moon:** 0.5 mm	**Sun:** 19.8 cm

Draw a scaled model of the Earth below:

Draw a scaled model of the Moon below:

Draw a scaled model of the Sun below:

SCALE MODEL OF SIZE AND DISTANCE

We can also create scaled models to represent the distance things are from each other.

The Moon is _________________ kilometers away from the Earth.
The Sun is ___________________ kilometers away from the Earth.

Fill in the blanks: The __________ is much closer to the Earth than the ________.

Create your scaled model

If the Earth and Moon were the sizes from our scale model on page 3, they would be _________ cm apart from each other.

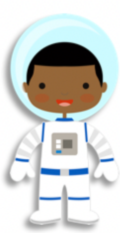
DIRECTIONS:

1. Label the 2mm circle on the left side of the page "Earth".
2. Measure 5.5 cm to the right and draw a small dot to represent the 0.5mm scaled Moon. Label it "Moon".

PREDICT: If the Earth and Moon are 5.5cm away from each other in our model, predict how far you think our 19.8cm scaled Sun would be from Earth.

Hint: It will NOT fit on this paper! Use the unit centimeters or meters for your prediction.

My Prediction: _________________ Actual Distance: _________________



My observations about the distance and size of objects:

Name: ____________________
Date: ____________________

ANALYSIS OF SCALE MODELS

1. What do you notice about the distance of the Earth to the Moon, compared to the distance of the Earth to the Sun?

2. If the Sun is actually so much bigger than the Moon, then why do you think they look like they are about the same size from Earth?

3. Are the models we made at a smaller, larger, or same size scale as the actual Moon, Sun, and Earth? How do you know?

4. Why do scientists use scale models to represent very large or very small objects? ____________________

Objective: I DID create a scale model of the Earth, Moon, and Sun to compare their sizes and distances from each other.

5. Which is larger, the size of the Sun, or the empty distance between the Sun and Earth?

____

____

____

____

6. Why do you think we didn't draw a model that included both the correct size AND distance for the Earth, Moon, and Sun on our papers?

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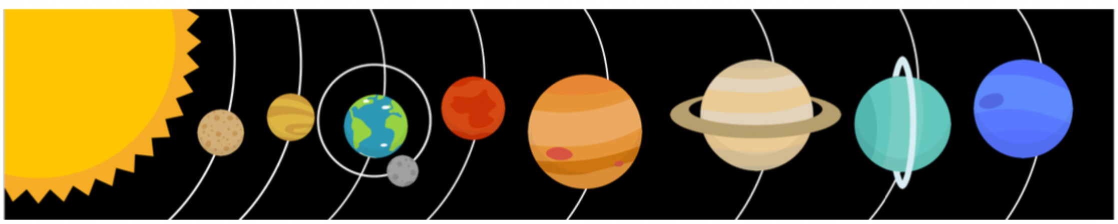
7. Based on what we've learned about scale models in this lesson, is the picture of the Solar System below drawn to scale? Why or why not?



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Objective: I DID create a scale model of the Earth, Moon, and Sun to compare their sizes and distances from each other.