Kaylee Crowder
Summer 2022

Unit Title: Scale Factor and the Solar System
Grade Level: 6th-7th
Duration: 9 class periods of 50 mins each.
Standards Addressed:

Kentucky Academic Standards for Science/NGSS Performance Expectations 06-ESS1-3 (NGSS:**MS-ESS1-3**) Analyze and interpret data to determine scale properties of objects in the solar system.		
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts:
Developing and Using Models (KAS) Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems. Develop and use a model to describe phenomena. (06- ESS1-1),(06-ESS1-2) **Analyzing and Interpreting Data (KAS & NGSS)** Analyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis. Analyze and interpret data to determine similarities and differences in findings. (06-ESS1-3)	N/A	**Systems and System Models** Models can be used to represent systems and their interactions. (06-ESS1-2)

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Kentucky Academic Standards/Common Core State Standards:

Math:

KAS Math:

KY.6.RP.3 Use ratio and rate reasoning to solve real-world and mathematical problems.
c. Use ratio reasoning to convert measurement units; manipulate and transform units appropriately when multiplying or dividing quantities.
MP.1, MP.4, MP.7

KY.7.RP.2 Recognize and represent proportional relationships between quantities.

KY.7.G.1 Solve problems involving scale drawings of geometric figures, including computing actual lengths and areas from a scale drawing and reproducing a scale drawing at a different scale.
MP.1, MP.2, MP.5

CCSS Math:

CCSS.MATH.CONTENT.6.RP.A.3
Use ratio and rate reasoning to solve real-world and mathematical problems, e.g., by reasoning about tables of equivalent ratios, tape diagrams, double number line diagrams, or equations.

CCSS.MATH.CONTENT.7.RP.A.3
Use proportional relationships to solve multistep ratio and percent problems. Examples: simple interest, tax, markups and markdowns, gratuities and commissions, fees, percent increase and decrease, percent error.

CCSS.MATH.CONTENT.7.G.A.1
Solve problems involving scale drawings of geometric figures, including computing actual lengths and areas from a scale drawing and reproducing a scale drawing at a different scale.

Other Standards

Kentucky Academic Standards Visual and Performing Arts:
VA Anchor Standard 2: Organize and develop artistic ideas and work

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VA:Cr2.1.6 Demonstrate openness in trying new ideas, materials, methods, and approaches in making works of art and design. -

Essential Questions:

How can scale models be used to help us understand the world around us?

Unit Purpose:
Ratio and proportional reasoning is an essential foundational concept introduced in the 6^{th} grade. Within the domain, unit conversion is a skill that is often taught in isolation and is the cause of frustration for many students (in my experience). In 7^{th} grade ratios and proportional reasoning is drawn upon for students to solve problems with scale drawings. When students are unsuccessful at building a solid foundation with proportional reasoning, they struggle greatly with scale drawings. Due to this, the lesson uses scale properties for objects in the solar systems to add context. The unit will begin with a common poem students are familiar with to set the stage for using proportions and scale. Students will then create a scaled version of the solar system on receipt tape to launch the lesson. After scale is discussed and the need for unit conversions are uncovered, students will create a more precision scale model using google sheets to display both a scale model of distance and planet size. These scale models will be used to create a class scale drawing/3D solar system model in the gym. Next, students will look at an image of water on Mars, taken from NASA's Mars Orbiter. Using a ruler, they will measure physical properties displayed on the image (in millimeters) and then convert those measurements to meters and kilometers. Lastly, students create their own scaled image of the Mars Rover Landing Site and the Bonneville Crater. Students will be shown multiple images from Mars that highlight elements of art. Students will create their own masterpiece that meets the required scale (using unit conversions) and clearly include at least two elements of art discussed. All three activities integrate both science and math, while the third activity integrates art as well. Allowing students the opportunity to synthesize their learning into the one culminating art product (their scaled drawing of the Mars Rover Landing Site) gives them the chance to work at a DOK Level 4 (extended thinking). To complete the many tasks in this lesson students will have to strategically analyze, reflect on their solution paths, and change their approaches at times to produce a coherent final product that used sophisticated and creative thinking. By integrating math, science, and art students will employ problem solving strategies and use skills from multiple subject areas to generate their product. This will provide context and motivation for students to engage at high levels.

These lessons will require students to reason abstractly and quantitatively (SMP 2), model with mathematics (SMP 4), use appropriate tools strategically (SMP 5), and attend to precision (SMP 6). Because this lesson is designed to be an integrated STEM unit to be conducted in a math classroom, the lesson is a bit heavier on the Standards for Mathematical Practice. The lessons ask students to reason abstractly and quantitatively by requiring students to contextualize and decontextualize the measurements as they scale up/scale down and convert between units. Students model with mathematics in the lessons when they create ratios, proportions, and equations to represent the unit conversions at hand. Students use tools appropriately throughout the unit as they use their rulers to make careful measurements. Lastly and possibly most importantly, students must attend to precisions. It will be brought to their attention during the unit if they are off on their measurements by even a millimeter, that could be representative of an entire kilometer by the end of the task. Precision must be a focus.

Differentiation of Instruction: This lesson can be adjusted to meet the various needs of my students in a variety of way. For example, the Slow Reveal Graph is intentionally designed to have a low floor and high ceiling meaning learners of all abilities can engage. If needed, students can be given printed graphs in the form of slides so they can better compare the similarities and differences. For the Solar System Scroll activity, students can complete a similar task that addresses the same standard. Students needing differentiation can be given a string cut to a predetermined length by me and beads of different sizes to represent planets. Students will place the beads in the predicted places, when it is time to check the accuracy of their predictions, students can hold their strings up to my model. They can then correct the placement of the three planets that they had the furthest off from my placement. Since all student strings will be the same length, myself or a collaborating teacher can assist students needing differentiation at the small group table.
During days 3-6 students will be working in mixed ability groups to create the scale model on google sheets as well as the class 3D model. Groups needing additional assistance will receive potential formulas to use that will meet the constraints they have preselected.
Next for the Water on Mars Task, students will be given scaffolds to assist them through the task. The task has the steps written out already, I placed guiding questions and equations as needed on student handouts. Students with significant needs can be grouped at the small group table for individualized assistance.

Unit Outline:

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Day	Lesson Title	Activities
1	1 Inch Tall	• Read 1 Inch Tall Poem • 1 Inch Tall Activity
2	Solar System Scroll	• Slow Reveal Graph • Solar System Scroll
3-4	Scale Models and Spreadsheets	• Notice & Wonder: Solar System Photo • Create a Solar System Scale Model with a Spreadsheet
5-6	Class Solar System Model	• Which one doesn't belong? • Class Solar System Model build in school gym
7	Water on Mars	• Water on Mars Activity
8	Mars Rover Landing Site Art	• Cosmic Art • Create Art of Mars Rover Landing Site to Scale
9	Mars Rover Landing Site Formative Assessment	• Unit Assessment

Measurable Student Learning Objectives:

- Students will be able to construct a two-dimensional model of the solar system that accurately displays the distance between the planets using an appropriate scale factor. (DOK 3)
- Calculating the scale distances between sun and planets by creating a formula in your spreadsheet. (DOK 3)
- Create and display a scale model of the solar system. (DOK 4)
- Students will be able to solve problems using scale drawings. (DOK 2)
- Students will be able to create a work of art using new ideas to display the Mars Rover Landing Site using an appropriate scale factor. (DOK 4)

Unit Materials:

- Not-to-scale solar system model images
- Computer
- Spreadsheet (Google Sheets)
- Distance markers
- Paper

- Pencil
- Receipt Tape
- Yarn
- Tape
- Colored pencils
- Centimeter ruler
- Compass
- Measuring Tape
- Solar System Reference Guide (see link or images)
- Scale Distance Google Sheet (see link or images)
- Scale Size Spreadsheet (see link or images)
- Scale Size and Distance Spreadsheet (see link or images)

Day 1:

Engage
Teacher will read Shel Silverstein poem, One Inch Tall

Explore
Students will cut a piece of yarn or string to represent their height. The string's length should be equal to the student's height. To relate back to the book, the string will represent one inch. Students will create a one inch ruler with the string, marking halves, fourths, eighths, and sixteenths using tape.
Students will now measure eight items around the room with their "one inch ruler". The height of each item should be recorded.

Explain
The teacher will lead a class discussion around how one might determine the actual height of one of the measured items using scale factors and/or proportional reasoning. The teacher will use his/her own one inch ruler and a measurement from the room to model the process.

Elaborate
Students will use a strategy from the discussion to determine the actual measurements of their eight selected objects.

Evaluate

Students will use a tape measure to record the actual measurements of their eight items and reflect on why there might be variations.

Day 2:

Engage

Slow Reveal Graph: Length of {Earth} Years on Different Planets

The teacher will open the class by sharing the first graphical display in the Slow Reveal Graph: Length of {Earth} Years slide deck. The teacher will ask students, “What do you notice? What do you wonder?” Students will be given the opportunity for silent personal response and then will have the chance to share out. The teacher will record responses on chart paper. The teacher will then go to the next slide that provides a bit more information/context to to the graph. The teacher will ask, “What new information did we learn? How does it change your thinking about the graph? What do you think each bar might represent? What might the dotted line represent?” Student discussion will follow the questions. The teacher will continue to the next slide, asking similar questions about the newly presented information on the graph. By the end of the slides, students will have discovered that the graph represents the number of Earth years it takes specific planets to make a trip around the sun. The teacher will then ask students to pick a planet and determine how old they would be on that planet. Student will share out with their table groups. Lastly, the teacher will ask how knowing the length of a year for each planet might relate to their distance from the sun and from one another. This will launch the next activity.

Explore

*Procedures gathered from NASA Jet Propulsion Lab Lesson

- Provide students with a strip of paper. On their paper, have students draw and label the Sun on one end and Pluto on the other, using colored pencils or markers. (For our purposes, we include Pluto, but Pluto is not a planet. If you prefer, you can label this end “Kuiper Belt.”)
- Take a guess! Have students fill in the remaining objects of our solar system in the space between the Sun and Pluto, paying attention to the relative distances between the objects. Are they evenly spaced? Or are some closer than others?

Explain

The teacher will guide students through the highlighted steps.

- Now with their guesses marked, students can find the actual distances between solar system objects. First, have them fold the strip in half. Using a bold color, label the midpoint (1/2 mark) Uranus.
- Now, take the side where you have the Sun labeled and fold it to the Uranus mark. The new crease (at the 1/4 mark) is where Saturn is located.
- Repeat the last step but this time with the Pluto side. This crease (at the 3/4 mark) is Neptune.
- Starting with the Sun again, fold the strip of paper to the Saturn mark. This new crease is at the 1/8 mark and is where we would find Jupiter.
- Repeat again, taking the Sun to the new Jupiter mark. This represents 1/16 and is where the asteroid belt is found.
- Repeating once more, at the 1/32 mark, we find Mars.
- That means that all of the remaining inner planets (Earth, Venus and Mercury) are between Mars and the Sun. So when you hear them called the “inner planets,” there is a good reason why!

Elaborate

Have students add a key to their scroll to identify which marks are guesses and which are the actual planet locations.

Evaluate

After students have the accurate planet placements marked on their scroll, the teacher will ask them to measure the distance from the sun to Earth with their rulers (in mm). Once students have their distances noted. The teacher will model how to use the actual distance to determine the scale factor used in their scroll. The students will then determine their scale factors.

Day 3-4:

Engage

The teacher will display an image of the solar system that does not show an accurate scaled distance between the planets. Students will be given the opportunity for personal response to record what they notice and what they wonder. The teacher will ask students to share their noticings and wonderings. Next the teacher will display an image of the solar system that does show an accurate representation of scaled distances. The same process for notice and wonder will be used. Then the teacher will explain that many times images do not show the accurate scale because it is difficult to display with the constraints of the textbook/image sizing. Today, they will be creating their own scale models using google sheets.

Explore/Explain (the teacher will go between the two stages depending on the need of the class and individual groups)
Students will be working in groups of 3-4.

1. Have students open the Scale Distance spreadsheet, or guide them through creating a similar spreadsheet layout.
2. With students, point out the distances in astronomical units (au) from the Sun to each planet. If students will input the distance data themselves, have them do that now. See the Solar System Sizes and Distances reference guide.
3. Decide or allow the class to decide how many centimeters will represent one astronomical unit (e.g., 10 cm = 1 au). This is your model's scale value. In other words, how far will Earth be from the Sun in this model?
    - Note: When 1 au = 10 cm, the scale distance to Neptune will be about 10 feet. Keep this in mind when considering the area you have to work with.
4. Have students come up with a formula for their spreadsheet to calculate how many centimeters each planet will be from the Sun in the scale model.
    - The formula should multiply the au value by the scale value determined in Step 3. This will give students the scale distance to each planet in centimeters.
    - Enter the multiplication formula into a cell in the cm column.
    - A spreadsheet multiplication formula follows this format: =B3*10, where B3 is the cell with a planet's au distance and 10 is the scale value. B refers to the cell column and 3 refers to the cell row.

Elaborate
Discussion around the question: How does using both scale size and distance in a model differ from a model that uses only scale size or distance?

Evaluate

Student spreadsheets should accurately calculate the scale size of and/or distances to all the planets. Students should be able to predict what would happen to the size and distance values in the model if the distance to or diameter of a single planet changes.

Day 5-6:

Engage

Which one doesn't belong? Students will complete "Which one doesn't belong?" with various solar system pictures. There is no one correct answer. Students will need to make note of scaled distances, planet sizes, etc.

Explore

Students will be working in the same groups from day 3-4.
The class will decide where in the room their sun shall be place. That spot will be marked on the gym floor.
Next, student groups will be assigned a planet. The teacher will display the precise measurement of the gym that will be used for the solar system. Using the spreadsheet created on the previous days, students will calculate the scaled size (for the gym) of their planet.

Explain

The teacher will guide discussion around the scaled sizes each group calculated. Then guide the entire class on the scaled distances from the sun their planets should be place. Once the placement has been determined, student groups will mark that on the floor.

Elaborate

Student groups will construct a 3D scale model of their planet using the supplies provided.

Evaluate

3D models should be placed in the correct sport (according to distance) and be the correct scaled size.

Day 7:

Engage

See, think, wonder- The teacher will guide students through See, Think, Wonder with a photograph of Mars. The teacher will select a question about water on Mars to discuss. If a question of that nature is not asked, the teacher will guide students there.

Explore

The teacher will assign each (previously created) group to complete steps one through four outlined on the task. The teacher will set a timer for 10 minutes. While student groups are working, the teacher will circulate around the room offering scaffolds, support and guiding questions. As the teacher circulates they will make note of students using proficient strategies to solve the problems outlined by the scale drawing.

Explain
After the 10 minutes are up, the teacher will call on the students noted who had proficient strategies to share out their solution path. The teacher will emphasize the students' strategies and solution pathways NOT the answer. After multiple students have presented, the class will discuss similarities in all of the strategies.

Elaborate
The teacher will then ask students to complete the rest of the task in the remaining 10 minutes

Evaluate
As an exit slip the students will write an written explanation for one of the 4 tasks assigned.

Day 8:
Engage
The teacher will share that oftentimes mathematics is reflected in art. Scale drawings are one example of this.The teacher will show students the PowerPoint slides linked in the Art and the Cosmic Connection slides, asking students to make note of the elements they see in each Cosmic artistic piece. The teacher will also keep a running list of artistic elements with a printed example from the slides posted on the board.

Explore/Explain/Elaborate

After all slides are viewed, the teacher will show the students a picture of the Mars Rover, Spirit, landing site. The students will be tasked with creating a scale drawing that includes at least two of the elements of art found in the Cosmic Connection slides. The teacher will provide students with the actual measurements of the Bonneville crater and students will have to determine the new size that will accurately represent it within the parameters of the paper provided. The teacher will give assistance as needed.

Evaluate
Student drawings will be scored for accuracy in scaled sizes of the crater and other aspects shown in the photograph.

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<u>Day 9:</u>
Assessment

The teacher will give each student a copy of the Mars Landing Site task. Students will have 15 minutes to complete steps 1-3 individually. The teacher will then bring the class together to discuss important aspects noted while circulating the room but no solution paths or strategies will be explicitly shared. The teacher will then give the class the remaining 20 minutes to complete questions 1-5.

Assessment:
This NASA, Mars Orbiter image of the Mars Rover, Spirit, landing area near Bonneville Crater. The width of the image is exactly 895 meters. (Credit: NASA/JPL/MSSS). It shows the various debris left over from the landing, and the track of the Rover leaving the landing site. The scale of an image is found by measuring with a ruler the distance between two points on the image whose separation in physical units you know. In this case, we are told the width of the image is 895 meters.
Step 1: Measure the width of the image with a metric ruler. How many millimeters wide is it?
Step 2: Use clues in the image description to determine a physical distance or length. Convert to meters.
Step 3: Divide your answer to Step 2 by your answer to Step 1 to get the image scale in meters per millimeter to two significant figures. Once you know the image scale, you can measure the size of any feature in the image in units of millimeters. Then multiply it by the image scale from Step 3 to get the actual size of the feature in meters to two significant figures.

Problem 1: About what is the diameter of Bonneville Crater rounded to the nearest ten meters?
Problem 2: How wide, in meters, is the track of the Rover?
Problem 3: How big is the Rover?
Problem 4: How small is the smallest well-defined crater to the nearest meter in size?
Problem 5: A boulder is typically 5 meters across or larger. Are there any boulders in this picture?

Mastery: Student answers at least 4 of 5 questions correctly.
Approaching Mastery: Student answers 3 questions correctly.
Novice: Student answers 1-2 questions correctly.

**Consideration will be given to students who use appropriate strategies but have* *simple mathematical errors.*

Resources

Laib, J. (2022, March 18). *Slow reveal graphs*. Slow Reveal Graphs. Retrieved July 15,2022, from https://slowrevealgraphs.com/

NASA. (2022, May 31). *Educator guide: Solar system scroll*. NASA. Retrieved July 15, 2022, from https://www.jpl.nasa.gov/edu/teach/activity/solar-system-scroll/

NASA. (n.d.). *Welcome to space math @ NASA !* NASA. Retrieved July 15, 2022, from https://spacemath.gsfc.nasa.gov/

Mars Rover Landing Site 31 - NASA. (n.d.). Retrieved July 15, 2022, from https://spacemath.gsfc.nasa.gov/weekly/4Page48.pdf

NASA. (2020, December 31). *Educator guide: Art and the cosmic connection*. NASA. Retrieved July 15, 2022, from https://www.jpl.nasa.gov/edu/teach/activity/art-the-cosmic-connection/

NASA. (2021, October 11). *Educator guide: Create a solar system scale model with spreadsheets*. NASA. Retrieved July 15, 2022, from https://www.jpl.nasa.gov/edu/teach/activity/create-a-solar-system-scale-model-with-spreadsheets/

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