LESSON TITLE: Collison or Near Miss: The Science Behind Celestial Collision

Grade: 7

Subject: Science, Math, and Technology

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BIG IDEAS

System models can be used to visually represent the role of gravity in the orbital motion of celestial bodies in our solar system.

EDUCATION STANDARDS

MS-ESS1-2. Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system. [Clarification Statement: Emphasis for the model is on gravity as the force that holds together the solar system and Milky Way galaxy and controls orbital motions within them. Examples of models can be physical (such as the analogy of distance along a football field or computer visualizations of elliptical orbits) or conceptual (such as mathematical proportions relative to the size of familiar objects such as students' school or state).]

NGSS Performance Expectation(s)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts:
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.	ESS1.B: Earth and the Solar System • The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them. • The solar system appears to have formed from a disk of dust and gas, drawn together by gravity.	Systems and System Models • Models can be used to represent systems and their interactions. - Connections to Nature of Science Scientific Knowledge Assumes an Order and Consistency in Natural Systems • Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation.

Common Core State Standards: Use your state standards if Common Core is not applicable in your state. You are encouraged to list the CCSS and your state standards.

Math:

MP.4 Model with mathematics

ELA:

SL.8.5 Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest

E2. Build a strong base of knowledge through content rich texts

E5. Read, write, and speak grounded in evidence

E3. Obtain, synthesize, and report findings clearly and effectively, in response to task and purpose

MEASURABLE STUDENT LEARNING OBJECTIVES

Student will be able to ask questions about the cause and effect of asteroids and meteoroids colliding with Earth.

Students will be able to develop a model of orbital motion consisting of two celestial bodies to test the effect of changing radius and mass on gravity.

Students will be able to construct an explanation of why some celestial bodies fall from the sky while others do not.

Students will be able to use evidence to predict if a celestial body will fall from the sky.

Students will be able to use evidence to determine organizational structure of our solar system, that is, the patterns in spatial location of celestial objects in respect to the Sun.

Students will able to use evidence to reason for orbital motion of a comet and cause of meteor showers when Earth's path crosses the debris left by a comet.

STEM INTEGRATION

Integration of SEM and Enhancement of Students' Understanding

Science (S): Students develop and explain models of orbital motion of celestial objects in our solar system.

Mathematics (M): Students are creating data tables and graphs of orbital motion variables to practice data management, analysis, and interpretation skills.

ELA (E): Students obtain and communicate essential disciplinary language such as gravity, orbital motion, and velocity to aid/apply in constructing explanation of "what was figured out" from the modeling and data collection and analysis exercises.

Logical Integration of SEM and Science Practices: Using a culturally relevant phenomenon allows for a logical integration of three disciplines. To figure out the phenomenon, students *blur the boundaries among the disciplines* of science, ELA, and math using an interdisciplinary approach (Kelley, 2010; Vasquez, 2015). In essence, all three disciplines are critical to figuring out the phenomenon. To figure out the phenomenon requires understanding of the *scientific laws* about orbital motion (McGowan, 2025). This is accomplished through interacting with the scientific simulations. Specifically, figuring out the phenomenon entails that students understand and explain the (a) role of gravity, (b) masses of the celestial objects, (c) distance between the celestial bodies in the hierarchy system, and (d) orbital velocity in the orbital motion of celestial bodies. Since scientific laws are also mathematical models (National Council of Teachers of Mathematics, 2000; NSTA, 2020, January), students need to de/construct the relationships between/among the variables. This requires students to use mathematical tools such as data tables for collecting data and graphs to determine the relationship between variables. To express their understanding, students obtain and use both science disciplinary and academic languages (Achieve, 2013a) to engage in scientific practices such as asking questions, writing scientific arguments, and constructing explanations.

NATURE OF STEM

Summarize how your lesson addresses the "nature of" science, technology, engineering, math, etc. as discussed in the Methods of STEM course.

In the 5E lesson, students will interact with three nature of science tenets (NOSTs) from Appendix H. During the explore and evaluate phase of the lesson, students use 4 simulations—CK-12 PLIX Interactive, My Solar System, Eyes on Asteroids, Eyes on the Solar System, and Meteor Showers as Seen From Space—to make observations to reinforce the NOST that "science investigations use a variety of methods and tools to make measurements and observations" (Achieve, 2013b, p. 5). In constructing their explanative drawing and writing their scientific arguments in the explain and elaborate phases respectively, students used evidence to write their claims and to construct their explanations to support the NOST that "science knowledge is based upon logical and conceptual connections between evidence and explanations" (Achieve, 2013b, p. 5). During the explore phase, using the simulation activities, students identify patterns in the data which reinforce the NOST that "science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observations" Achieve, 2013b, p. 6).

MATERIALS NEEDED

1. Video: NASA's plan to save Earth from a giant asteroid
2. EdPuzzle Account
3. Read: CK-12 Foundation: Orbital Motion
4. Model: CK-12 PLIX Interactive
5. Computer
6. PhET: My Solar System
7. Project Zero Thinking Routine: See, Think, Wonder
8. Project Zero Thinking Routine: I Used to Think…Now I Think…
9. Probe 27: Is the Moon Falling? Or Adaptation: Is the Moon Falling?
10. NASA's Eyes on Asteroids
11. NASA's Eyes on the Solar System
12. PowerPoint Plugin: PollEverywhere
13. Station#1: CK-12 data
14. Station#2: PhET data
15. Station#3: NASA data
16. Redway's Protocol for Explanative Drawings Construction
17. Redway's Protocol for Collaborative Scientific Argument
18. Meteor Showers as Seen From Space
19. Quiz: Using Meteor Shower Data as Evidence

ENGAGING CONTEXT/PHENOMENON

Students will view the video, *NASA's plan to save Earth from a giant asteroid*, to figure out why some celestial bodies fall out of the sky and others do not.

DATA INTEGRATION

In this lesson, four sets of data are being collected. In the **first data collection** station, students are collecting (i.e., data tables) and analyzing data (i.e., graphs) from the *CK-12 PLIX* Interactive to determine the relationship between (1) the effect of increasing mass on gravity and (1) the effect of increasing distance on gravity. In the **second data** collection station, students are analyzing data from the PhET simulation, *My Solar System*, to describe (using explanative drawings) that gravity is a predominantly inward-pulling force that can keep smaller objects around larger objects. Comparisons will be made for (1) a moon-planet orbiting system (2) a sun-planet orbiting system. In the **third data collection**, students are collecting data from NASA's *Eyes on Asteroids* interactive for asteroids' (1) composition, (2) size, and (3) distance from the Sun and compare the data to *NASA's Eyes on the Solar System* for planets' (1) composition, (2) size, and (3) distance from the Sun looking for patterns in the data sets. The **fourth data collection** occurs on the summative quiz in the evaluate phase, whereby students collect evidence from the simulation, *Meteor Showers as Seen From Space* (1) to describe the orbital motion of a comet (2) the cause of the comet's orbital motion, and (3) reason for meteor showers on Earth when the planet crosses path with debris from a comet.

TEACHER BACKGROUND KNOWLEDGE

1. See: Plummer, J. D. (2017). Chapter 10: Core Idea ESS1: Earth's place in the universe. In R. G. Duncan, J. S. Krajcik, & A. E. Rivet (Eds.), Disciplinary core ideas: Reshaping teaching and learning (pp. 185-203). NSTA Press.
    a. Notes:
        i. "planets and other solar system objects, such as comets and asteroids, maintain their orbits about the Sun, rather than flying off into space, due to the gravitational force of attraction between the object and the Sun" (p. 191).
        ii. "planets and other objects in stable orbits are traveling forward in their orbital trajectory at a velocity great enough to maintain a constant, roughly circular 'fall' about the Sun" (p. 191).
        iii. "Students' systematic exploration of solar system phenomena should also include organizing and classifying objects in the solar system toward a better understanding of the common properties and patterns of the solar system's constituents (Rubin et al. 2014)… This allows students to see how planets and other solar system objects with similar compositions and sizes (such as asteroids, comets, or Kuiper belt objects) are found at similar distances from the Sun" (p. 192).
2. See: Sampson, V., Murphy, A., Lipscomb, K., & Hutner, T. L. (2018). Lab 3: Teacher notes. Lab 3. Gravity and orbits: How does changing the mass and velocity of a satellite and the mass of the object that it revolves round affect the nature of the satellite's orbit? In V. Sampson, A. Murphy, K. Lipscomb, & T. L. Hutner (Eds.), Argument-Driven inquiry in Earth and space science: Lab investigations for grades 6-10 (pp. 78-99). NSTA Press.
    a. Notes:
        i. "An *orbit* is a regular, repeating path that one object in space takes around another one. Any object in an orbit around a planet or a star is called a satellite. A satellite can be natural, like planets (which orbit a star), moons (which orbit planets), and comets (which orbit stars). Or a satellite can be artificial, created by engineers and scientists and sent into space, such as the International Space Station (which orbits Earth), the Hubble Space Telescope (which orbits Earth), and the Cassini space probe (which orbits Saturn)" (p. 78)

ii. When sending an artificial satellite into orbit, it is important to consider Newton's first law: an object in motion will stay in motion unless something pushes or pulls on it. Without the force of gravity acting on it, an artificial satellite therefore moves in a straight line at a constant velocity. With the force of gravity acting on it, however, the artificial satellite is pulled toward the center of the object it is orbiting (usually a planet, but occasionally a moon or the Sun). This force causes the satellite to change direction. A satellite's velocity and the force of gravity acting on it therefore have to be balanced for the satellite to stay in orbit around a planet. If the satellite is moving too fast, it will not enter into an orbit at all and will fly off into space; but if it is moving too slow, it will be pulled into the planet and crash. When the velocity of the satellite and the force of gravity are balanced, the satellite will enter a stable orbit at a specific distance above the planet. Scientists use the term *orbital velocity* to describe how fast a satellite has to be moving in order to enter a stable orbit at a specific altitude… The shape of an orbit, the distance of an orbit, and the period of an orbit depend on three factors: (1) is the mass of the satellite, (2) the initial velocity of the satellite, and (3) the mass of the object that the satellite revolves around." (pp-78-79).

DIFFERENTIATION OF INSTRUCTION

1. Students are provided with an Edpuzzle to unpack the information from the video and also sentence stems from applicable thinking routines. Teachers should use their discretion to assign the various modifications to students who benefit from them.
2. I recorded videos on how to navigate the simulations for students to view as often as they need.
3. Students will be provided with graphic organizers (i.e., data tables) that are tiered from being more structured to less structured (Tomlinson, 1995)
4. Students will be provided with graphs that are tiered from being more structured (variables provided on the x and y axes to less structured (variables absent from the x and y axes).
5. Students will be provided with modeling graphic organizers that are tiered from being more structured (circles representing the moon-planet hierarchical system and the planet-sun hierarchical system) to less structured (no visual representations of the hierarchical systems).

REAL-WORLD CONNECTIONS FOR STUDENTS

A culturally responsive anchoring phenomenon is local or community-based, observable, puzzling, complex, and engages students in the STEM disciplines using the science and engineering practices crosscutting concepts, and disciplinary core ideas (Penuel & Bell, 2016; Vasquez, 2015). In essence, it "spark[s] curiosity and wonder" (Bozeman Science, 2019, July 9) for four reasons. First, the phenomenon, a potential asteroid crash on Earth, sparks curiosity because it threatens our survival. Second, the phenomenon treats Earth as a broad community; therefore, all citizens should be concerned. Third, historical records of similar cases are observable. Fourth, the sense-making processes of figuring out why this event occurs but is not observed in the orbiting motion of relevant celestial bodies trigger many complex questions that require the development of investigatory models (i.e. PhET simulation) to construct a logical explanation.

INTEGRATION POSSIBLE MISCONCEPTIONS

1. See: Plummer, J. D. (2017). Chapter 10: Core Idea ESS1: Earth's place in the universe. In R. G. Duncan, J. S. Krajcik, & A. E. Rivet (Eds.), Disciplinary core ideas: Reshaping teaching and

learning (pp. 185-203). NSTA Press.

2. Notes:
    a. “Many students are likely to have alternative ideas about the nature of gravity, such as the belief that there is no gravity in space or that gravity only extends as far as the Earth’s atmosphere (Williamson and Willoughby 2012). Students also often believe that only certain objects exert a gravitational force rather than all objects with mass (Plummer et al. 2015). And even when students have learned that planets are held in orbit around the Sun due to the Sun’s gravitational pull on them, students are often unsure why planets do not crash into the Sun because they are unable to articulate the role of the planets’ tangential velocity in maintaining the orbital motion (Plummer et al. 2015)” (p. 191).

LESSON PROCEDURE

5E	Details of 5E Lesson Implementation
Engage Introduce the lesson with an anchoring phenomenon. Facilitate student questions, discussion, etc. as appropriate. Learn about what students already know and want to know.	**Procedure:** In this phase, the teacher elicits students local/funds of knowledge about the phenomenon using the driving question, why do some celestial objects fall from the sky/space and others do not? Teacher plays the video: NASA's plan to save Earth from a giant asteroid Teacher discusses the difference between an open-ended and a close-ended question. Students ask open-ended and close-ended questions about the phenomenon **Modifications:** Students use the thinking routine: See, Think, Wonder to help with question generation. Students who need more scaffolding can complete the EdPuzzle prior to generating the questions. **Standards Addressed:** 1. E5. Read, write, and speak grounded in evidence. 2. ESS1.B: Earth and the Solar System **Formative:** Students share their open-ended questions in the Poll Everywhere app. Teacher “looks for” questions that require an elaborate explanation. *Sample questions from students:* 1. Why did the meteorite fall from space? 2. Where is the asteroid/meteorite coming from?

	3. Can scientists predict when other celestial objects will fall from space? 4. When will the next asteroid/meteorite fall from space? 5. Can the moon fall from space? 6. How is gravity involved in celestial objects falling from space? 7. Is an asteroid different from a meteor? 8. Can comets fall from space? **Components of the model** a. To make sense of a given phenomenon, students develop a model in which they identify the relevant components of the system, including: i. Gravity. ii. The solar system as a collection of bodies, including the sun, planets, moons, and asteroids. iii. The Milky Way galaxy as a collection of stars (e.g., the sun) and their associated systems of objects. iv. Other galaxies in the universe *Source: Evidence Statements* **Resources:** 1. NASA's plan to save Earth from a giant asteroid 2. PollEverywhere 3. See, Think, Wonder 4. EdPuzzle Account
Explore Plan for students to engage in hands-on activities that are designed to facilitate conceptual change.	**Procedure:** In this phase, students work in groups of 4 in 3 rotating stations to collect and analyze data. In the **first data collection station,** students are collecting (i.e., data tables) and analyzing data (i.e., graphs) from the *CK-12 PLIX* Interactive to determine the relationship between (1) the effect of increasing mass on gravity and (1) the effect of increasing distance on gravity. In the **second data collection station,** students are analyzing data from the PhET simulation, *My Solar System*, to describe (using explanative drawings) that gravity is a predominantly inward-pulling force that can keep smaller objects around larger objects. Comparisons will be made for (1) a moon-planet orbiting system (2) a sun-planet orbiting system. In the **third data collection,** students are collecting data from NASA's *Eyes on Asteroids* interactive for asteroids' (1) composition, (2) size, and (3) distance from the Sun and compare the data to *NASA's Eyes on the Solar System* for planets' (1) composition, (2) size, and (3) distance from the Sun figuring out patterns in the data sets. *Teacher Station Introduction:* 1. Teacher divides the class into heterogeneous groups of 4. 2. Teacher shares the 3 stations with students in a PowerPoint file and also a printed file. 3. Teacher plays the videos that shows students how to navigate the simulations and how to collect, organize, analyze, and interpret the data. (*Note. The associated differentiated video for a given station is also linked to first page of the PowerPoint for easy retrieval*).

	4. Teacher informs the students that they can work on the 3 stations in any sequence, but they must complete 1 station per class period and discuss their findings with the teacher in their small group conference. *Station Navigation for Students* 1. In Station#1, CK-12 simulation, students are collecting data to figure out the effect of changing mass and changing distance on gravitational force. 2. In Station#2, PhET simulation, students are changing mass in the system to figure hierarchy of the celestial bodies and the role of gravity in determining orbital motion. 3. In Station#3, NASA's Eyes on…simulations, students are collecting and comparing asteroids data with planets data to identify patterns related in solar system organization. **Modifications** 1. I recorded videos on how to navigate the simulations for students to view as often as they need. 2. Students will be provided with graphic organizers (i.e., data tables) that are tiered from being more structured to less structured (Tomlinson, 1995). 3. Students will be provided with graphs that are tiered from being more structured (variables provided on the x and y axes to less structured (variables absent from the x and y axes). **Standards Addressed:** 1. MP.4 Model with mathematics 2. SL.8.5 Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest 3. E3. Obtain, synthesize, and report findings clearly and effectively, in response to task and purpose 4. ESS1.B: Earth and the Solar System **Formative Assessments** *CK-12 Dataset: Radius vs. Gravity* Techer "looks for" data table that has radius in left column and gravity in the second column. Sample data can use an interval of 1 for the radius. Teacher "looks for collection of sufficient data to recognize a pattern in the data. Students can collect from 5 up to 8 sets of data. *CK-12 Dataset: Mass vs. Gravity* Techer "looks for" data table that has mass in left column and gravity in the second column. Sample data can use an interval of 3 for the mass. Teacher "looks for" collection of sufficient data to recognize a pattern in the data.

	Students collect no less than 3 sets of data. *CK-12 Graphs:* Teacher "looks for" graphs that using the graphic checklist VUTRIP (VUTRIP (V=variables, U=unit(s), T=title, R=range, I= interval, P= plot and connect) *Interpretation:* Teacher "looks for" interpretation of the graph that shows students figured out:

Relationships		
a	Students describe* the relationships and interactions between components of the solar and galaxy systems, including:	
	i.	Gravity as an attractive force between solar system and galaxy objects that:
		1. Increases with the mass of the interacting objects increases.
		2. Decreases as the distances between objects increases.

Source: Evidence Statements

PhET Dataset:

Teacher "looks for" model drawings that have symbols, language, interpretation, and logic that convey that students figured out:

3	Connections		
	a	Students use the model to describe* that gravity is a predominantly inward-pulling force that can keep smaller/less massive objects in orbit around larger/more massive objects.	
	b	Students use the model to describe* that gravity causes a pattern of smaller/less massive objects orbiting around larger/more massive objects at all system scales in the universe, including that:	
		i.	Gravitational forces from planets cause smaller objects (e.g., moons) to orbit around planets.
		ii.	The gravitational force of the sun causes the planets and other bodies to orbit around it, holding the solar system together.
	c	Students use the model to describe* that objects too far away from the sun do not orbit it because the sun's gravitational force on those objects is too weak to pull them into orbit.	
	d	Students use the model to describe* what a given phenomenon might look like without gravity (e.g., smaller planets would move in straight paths through space, rather than orbiting a more massive body).	

Source: Evidence Statements

NASA Dataset:

Teacher "looks for" students figuring out that:

1. Rocky planets are found closer to the Sun.
2. Asteroids are found between Mars and Jupiter.
3. The gaseous planets, Jupiter and Saturn are away from the Sun.
4. Uranus and Neptune the furthest away are ice giants.

Resources

1. Model: CK-12 PLIX Interactive
2. Computer
3. PhET: My Solar System
4. NASA's Eyes on Asteroids
5. NASA's Eyes on the Solar System

	6. Station#1: CK-12 data 7. Station#2: PhET data 8. Station#3: NASA data
Explain Facilitate opportunities for students to explain their understanding of concepts and processes and make sense of new concepts.	**Procedure:** In this phase, students are completing an explanative drawing of the conditions that could cause an asteroid to fall to Earth. Teacher should revisit the anchoring phenomenon video with the students. Teachers should brainstorm a checklist with students of what should be included in the explanative drawing. Teacher should provide a framework for explanative drawing construction. Students are independently constructing an explanative drawing on tabloid (11x17) paper. **Modifications** In small group instruction, the teacher can provide sentence stems to students who need more scaffolding in generating an explanation. **Standards Addressed** 1. ESS1.B: Earth and the Solar System 2. E5. Read, write, and speak grounded in evidence. **Formative** Teacher "looks for" students' explanative drawings to see if they figured out: 1. What is an asteroid? 2. Where are asteroids found? 3. Propose conditions (factors that change in the gravitational pull) that can alter an asteroid's orbit. **Resources** 1. Video: NASA's plan to save Earth from a giant asteroid 2. 11 x 17 Tabloid paper for explanative drawings 3. Colored pencils 4. Redway's Protocol for Explanative Drawings Construction
Elaborate Provide applications of	**Procedure:** In this section, students are applying their learning to an associated phenomenon, the Moon-Earth system. **Modifications** Students write a collaborate scientific argument. Each member of the group

<table>
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<td>concepts and opportunities to challenge and deep ideas; build on or extend understanding and skills.</td>
<td>takes turns in writing a segment of the argument after brainstorming possible responses.

Standards Addressed

1. ESS1.B: Earth and the Solar System
2. E5. Read, write, and speak grounded in evidence.

Formative Assessments

Teacher “looks for” response that shows that while the Earth’s gravity is pulling the Moon towards the Earth, the Moon will not crash into the Earth because the Moon is moving at constant velocity. If there was no gravity, it would fly off into space at a constant velocity. If there not moving, it would get pulled into the Earth’s atmosphere. Students are using evidence from the PhET simulation. Evidence can include both drawings and explanations.

Resources

1. Probe 27: Is the Moon Falling?
2. Adaptation: Is the Moon Falling?
3. Redway’s Protocol for Collaborative Scientific Argument</td>
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<td><h2>Evaluate</h2>Assess students knowledge, skills and abilities.</td>
<td>Procedure: In this phase, students are reflecting on how their thinking has changed.

Modifications: Students use the sentence stems from the Project Zero Thinking Routine: I Used to Think…Now I Think…to evaluate how their thinking has changed.

Standards Addressed:

1. ESS1.B: Earth and the Solar System
2. E5. Read, write, and speak grounded in evidence.

Formative Assessment:

Teacher “looks for” changes in thinking that incorporates use of the disciplinary symbols, language, and logic of the unit.

<table>
<tr><th colspan="3">Components of the model</th></tr>
<tr><td>a</td><td colspan="2">To make sense of a given phenomenon, students develop a model in which they identify the relevant components of the system, including:</td></tr>
<tr><td></td><td>i.</td><td>Gravity.</td></tr>
<tr><td></td><td>ii.</td><td>The solar system as a collection of bodies, including the sun, planets, moons, and asteroids.</td></tr>
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<tr><td></td><td>iv.</td><td>Other galaxies in the universe</td></tr>
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Relationships		
a	Students describe* the relationships and interactions between components of the solar and galaxy systems, including:	
	i.	Gravity as an attractive force between solar system and galaxy objects that:
		1. Increases with the mass of the interacting objects increases.
		2. Decreases as the distances between objects increases.

3	Connections		
	a	Students use the model to describe* that gravity is a predominantly inward-pulling force that can keep smaller/less massive objects in orbit around larger/more massive objects.	
	b	Students use the model to describe* that gravity causes a pattern of smaller/less massive objects orbiting around larger/more massive objects at all system scales in the universe, including that:	
		i.	Gravitational forces from planets cause smaller objects (e.g., moons) to orbit around planets.
		ii.	The gravitational force of the sun causes the planets and other bodies to orbit around it, holding the solar system together.
	c	Students use the model to describe* that objects too far away from the sun do not orbit it because the sun's gravitational force on those objects is too weak to pull them into orbit.	
	d	Students use the model to describe* what a given phenomenon might look like without gravity (e.g., smaller planets would move in straight paths through space, rather than orbiting a more massive body).	

Summative Assessment:

Quiz: Using Meteor Shower Data as Evidence

Resources:

1. Project Zero Thinking Routine: I Used to Think…Now I Think…
2. Meteor Showers as Seen From Space

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