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Using Planetary Orbits to Teach Gravity

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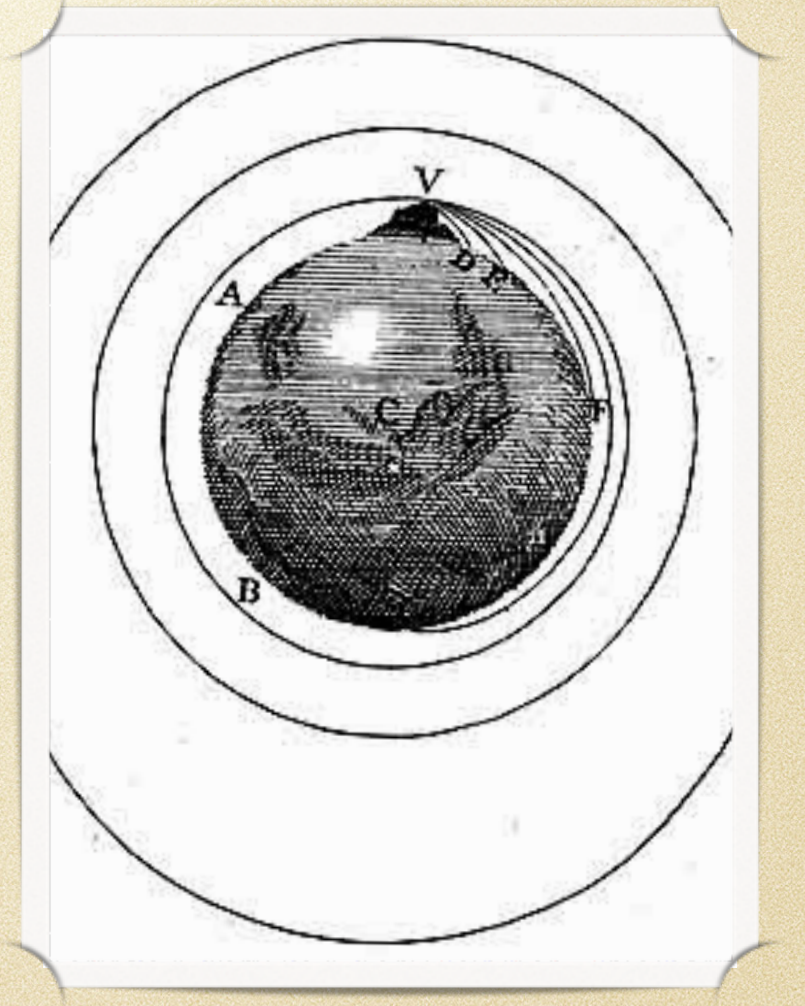
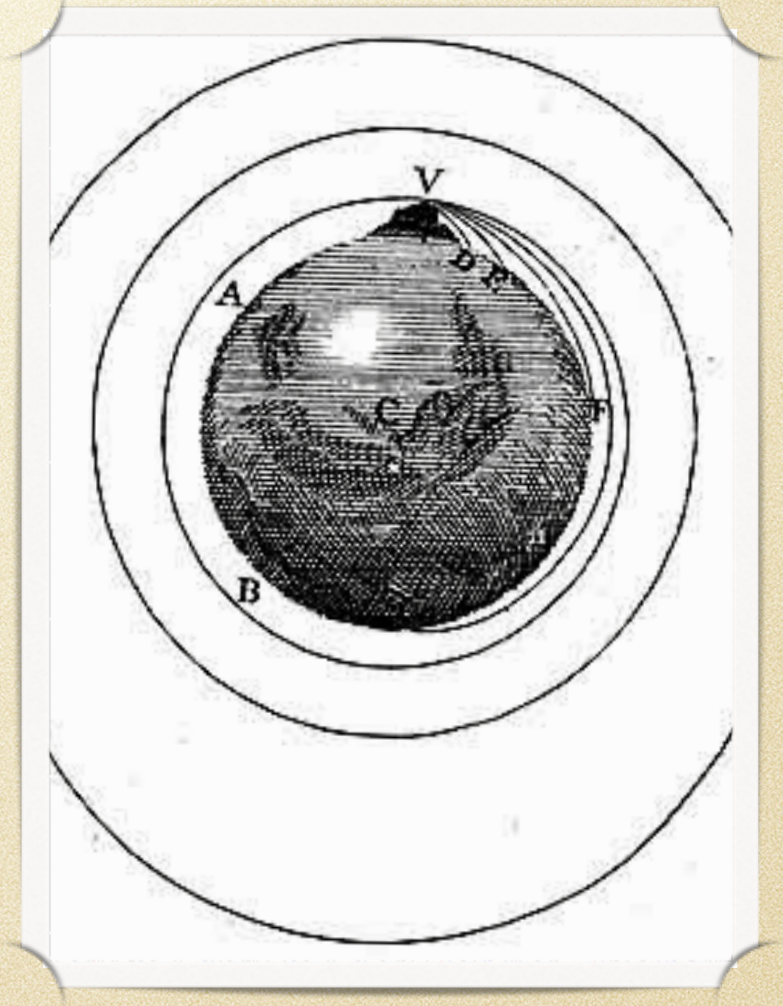
Our research shows us that students do not understand gravity's role in orbits.

- Research for a "Learning Progression" in Solar System Astronomy
- Interviews with 44 students grades 6 - college
- Most common answer to our questions about orbits indicates students think gravity acts alone



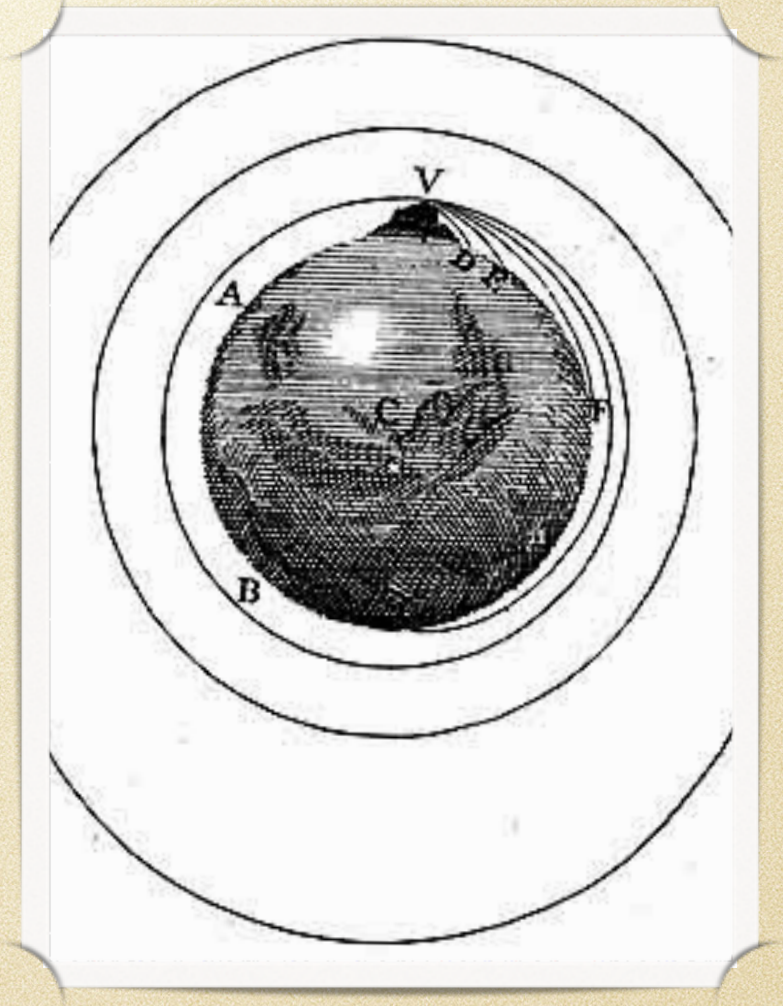
Students invented reasoning to describe how one force could create a nearly circular orbit.

- Students interviewed included high school physics students
- They had trouble taking their understanding of ballistic motion and forces in general from an Earth-based perspective and transferring that to the case of a test mass in space



Pennsylvania standards seem to reinforce misconceptions about gravity's role in orbits.

- In the 2010 version of the standards, the 10th grade standard read in part, "Explain how gravity is responsible for planetary orbits"



The NGSS are better, but still emphasize gravity perhaps to the detriment of student understanding.

MS.Space Systems

Students who demonstrate understanding can:

06-ESS1-1. **Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.** [Clarification Statement: Examples of models can be physical, graphical, or conceptual.]

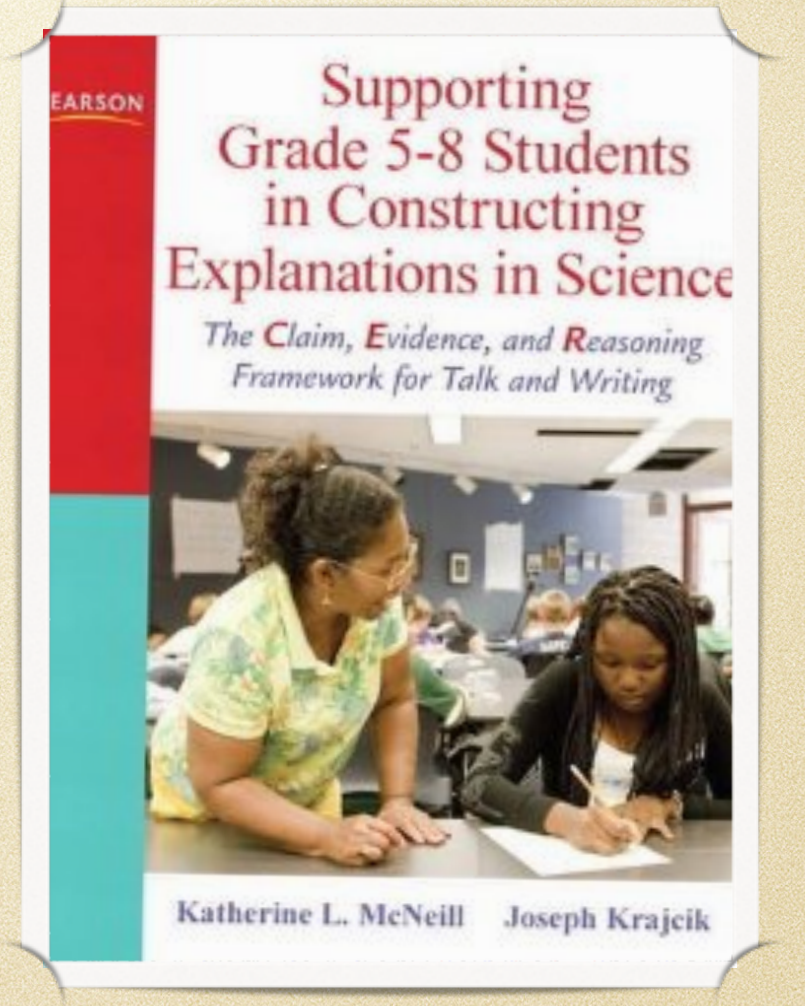
06-ESS1-2. **Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.** [Clarification Statement: Emphasis for the model is on gravity as the force that holds together the solar system and Milky Way galaxy and controls orbital motions within them. Examples 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 their school or state).] [Assessment Boundary: Assessment does not include Kepler's Laws of orbital motion or the apparent retrograde motion of the planets as viewed from Earth.]

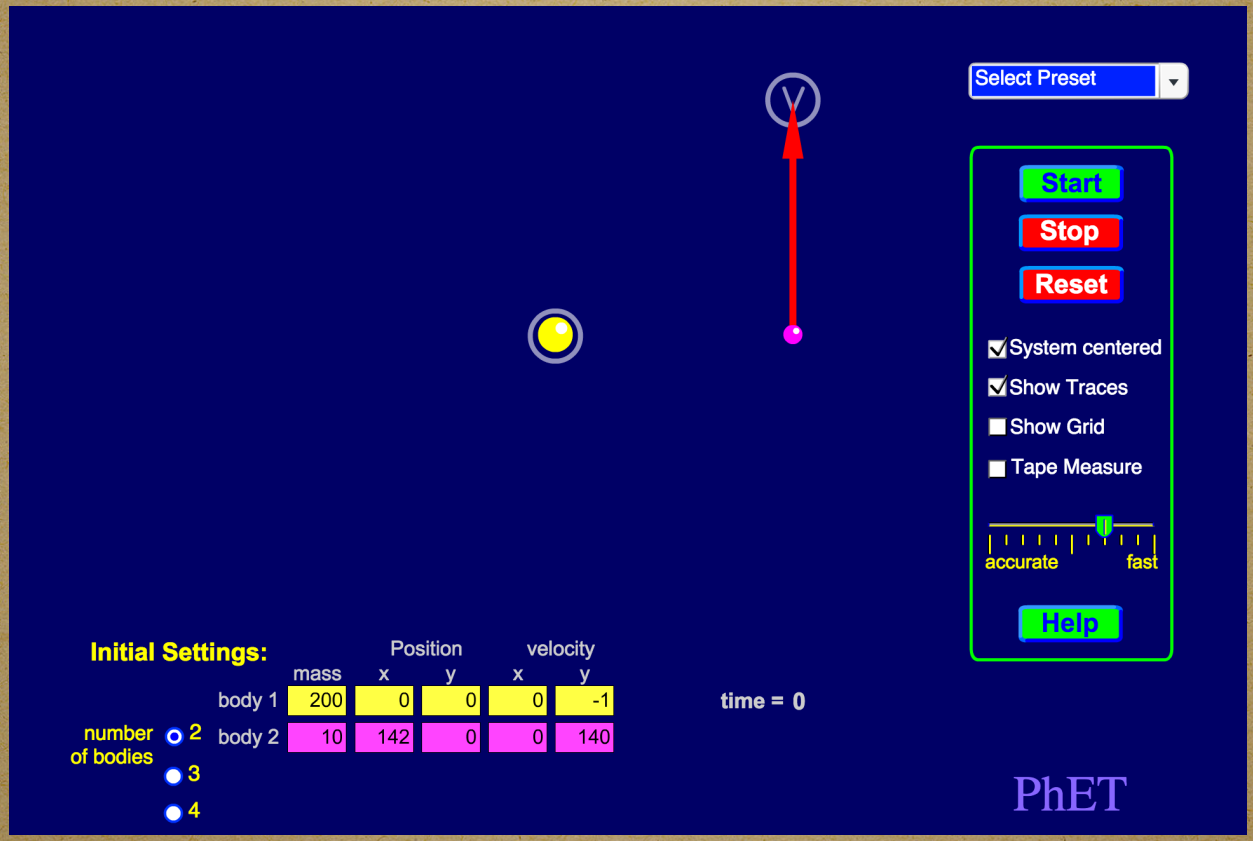
06-ESS1-3. **Analyze and interpret data to determine scale properties of objects in the solar system.** [Clarification Statement: Emphasis is on the analysis of data from Earth-based instruments, space-based telescopes, and spacecraft to determine similarities and differences among solar system objects. Examples of scale properties include the sizes of an object's layers (such as crust and atmosphere), surface features (such as volcanoes), and orbital radius. Examples of data include statistical information, drawings and photographs, and models.] [Assessment Boundary: Assessment does not include recalling facts about properties of the planets and other solar system bodies.]

We created a student investigation that uses a PhET simulation to guide them to understanding of the role of gravity in planetary orbits.

This investigation uses “CER”, and we have tested it with in-service teachers and pre-service teachers.

- Co-author and developer is a PA HS Physics teacher and PSU PhD candidate in Science Education
- She uses CER in her physics class
- In my experience with a 6th grade teacher, we have seen remarkable student learning using CER

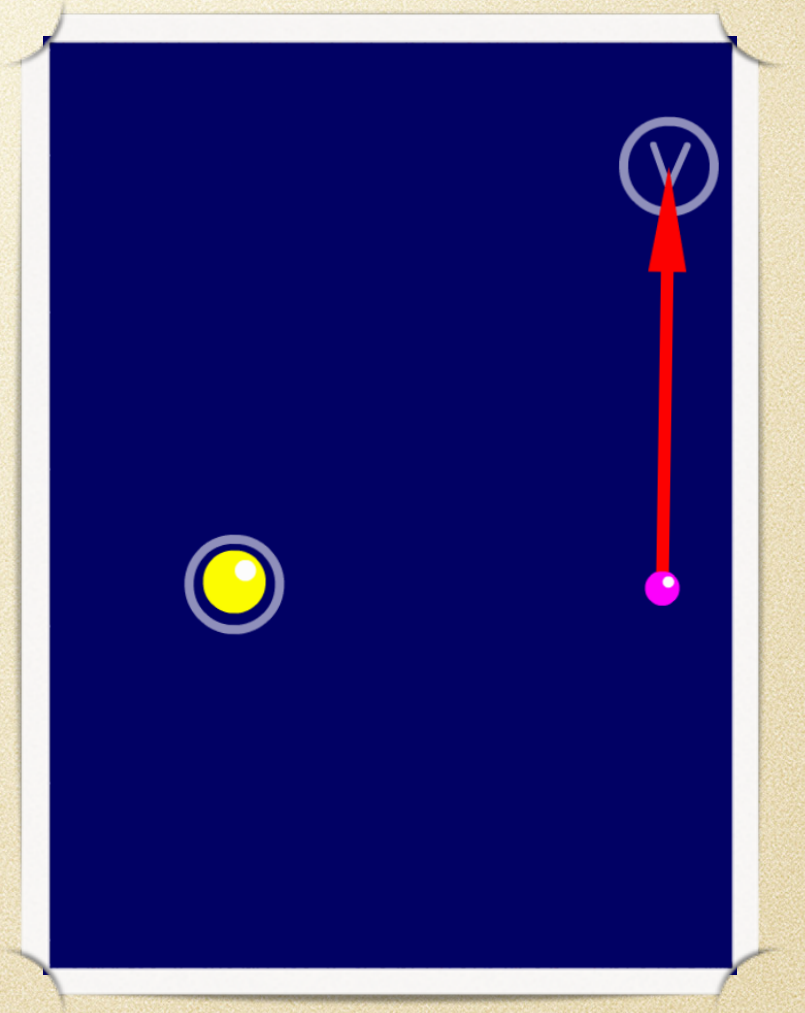




We are going to break up into small groups and use the "My Solar System simulation to model orbits and practice using CER as students would.

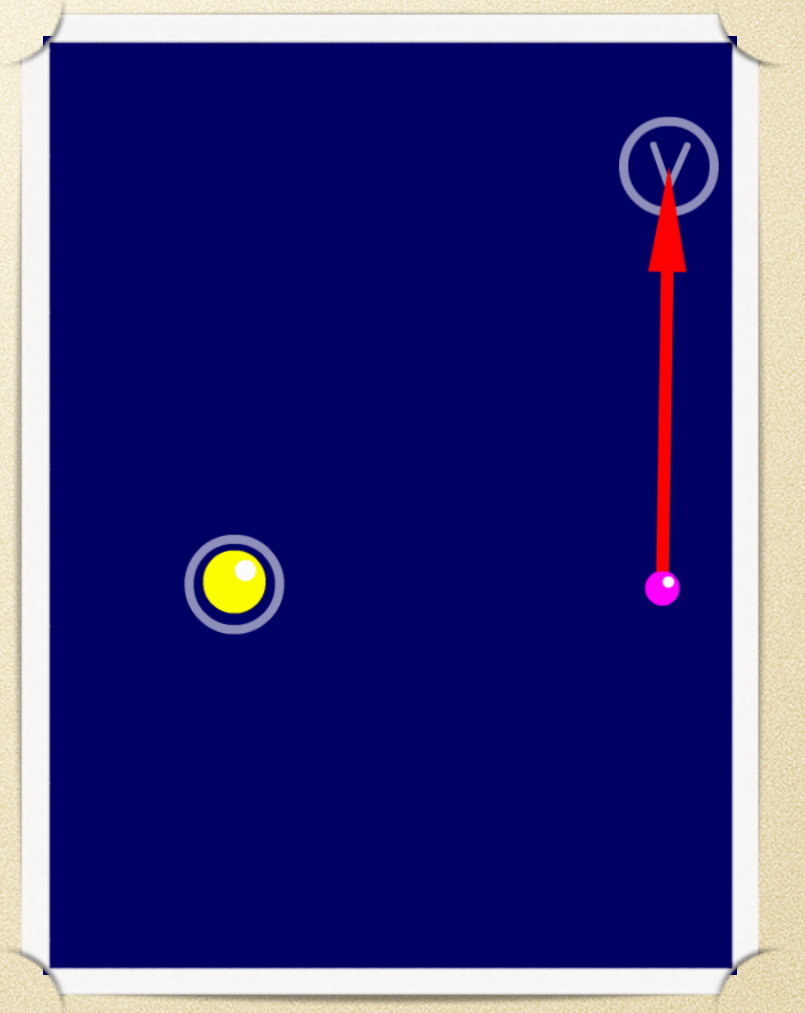
For novice students, first part of this is to familiarize themselves with the tool.

- Play around with varying mass, velocity magnitude, velocity direction, pre-sets, distance between Sun & planets, number of objects
- Share-out: What happened when you used parameters that did not produce a stable orbit?



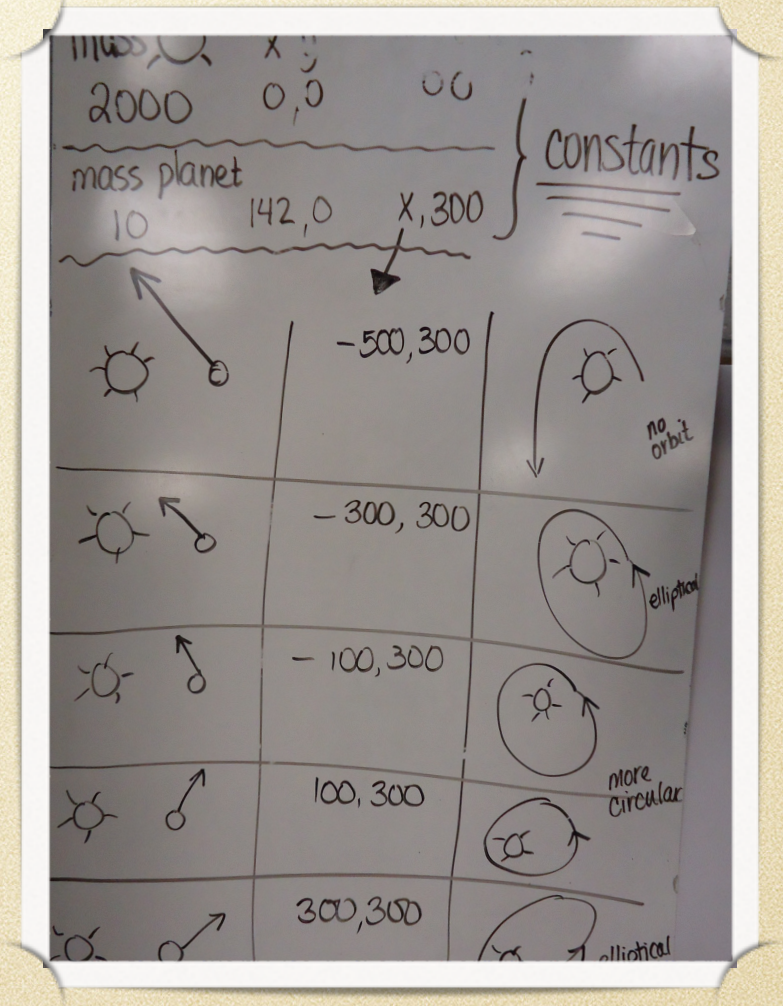
Next, we will divide up the work of varying these parameters to begin to address the investigation question.

- What factors are needed to produce a stable orbit that appears roughly similar to the orbits of the planets in our Solar System?
- Each group varies one parameter
- In your group, write a claim that addresses the investigation question using evidence from your investigation



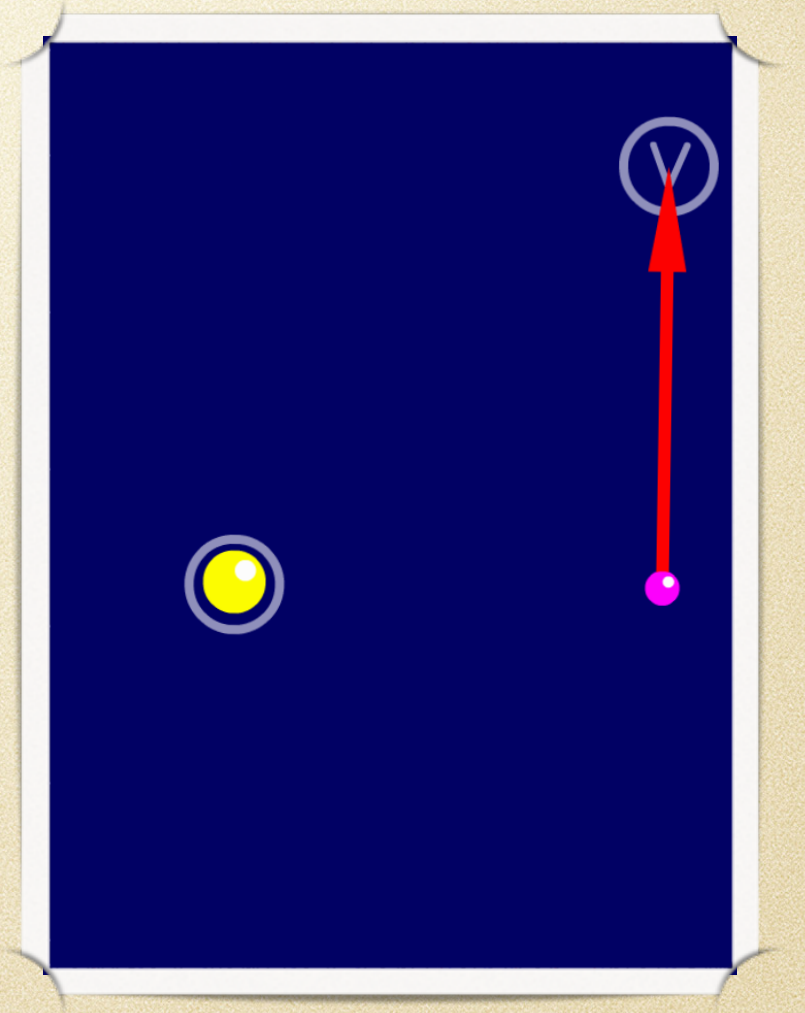
Hold a “Board Meeting” to give students the opportunity to share their results and look for patterns.

- Each group prepares a poster with their claims and evidence
- Put these up, give everyone time to scan the room
- Ask for volunteers to compare and contrast the results
- Reasoning is the hardest part, requires more work



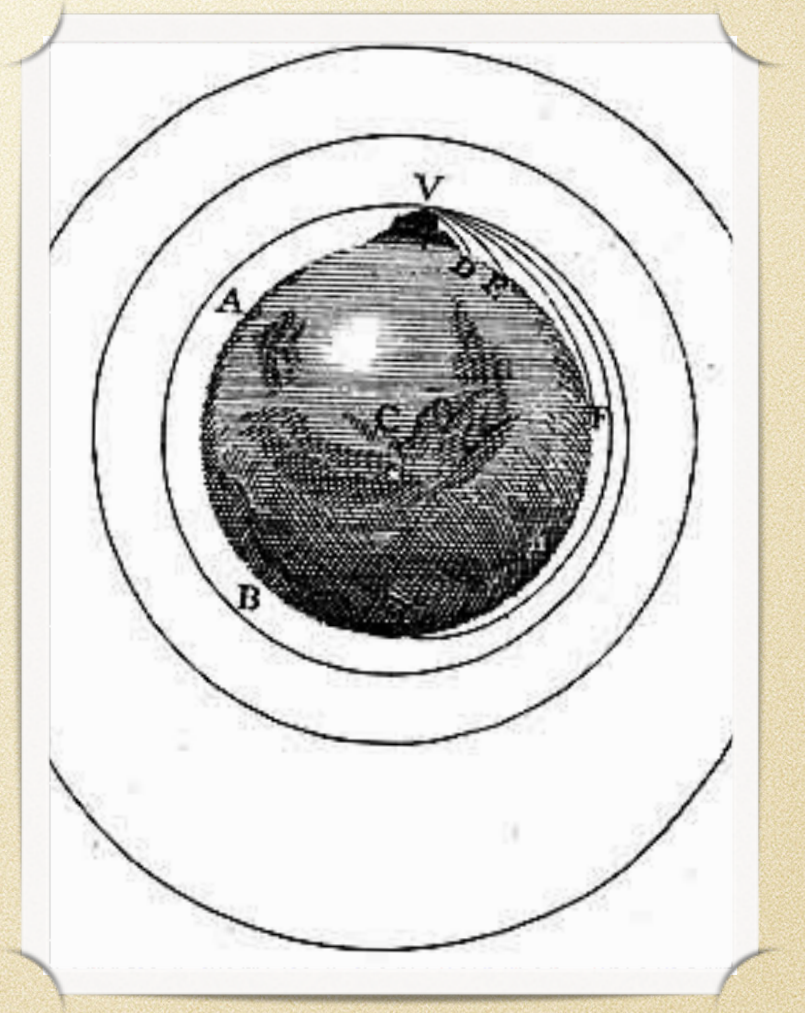
With our pre-service teachers, we added a second task with the model to give them more practice with the parameters

- Use the Sun-Moon-Earth pre-set, but change the masses to 1000, 0.01, 0.01
- Vary the magnitude of the velocity and distance between all three objects until you achieve two nested, nearly-circular orbits
- What is the pattern in their velocities?



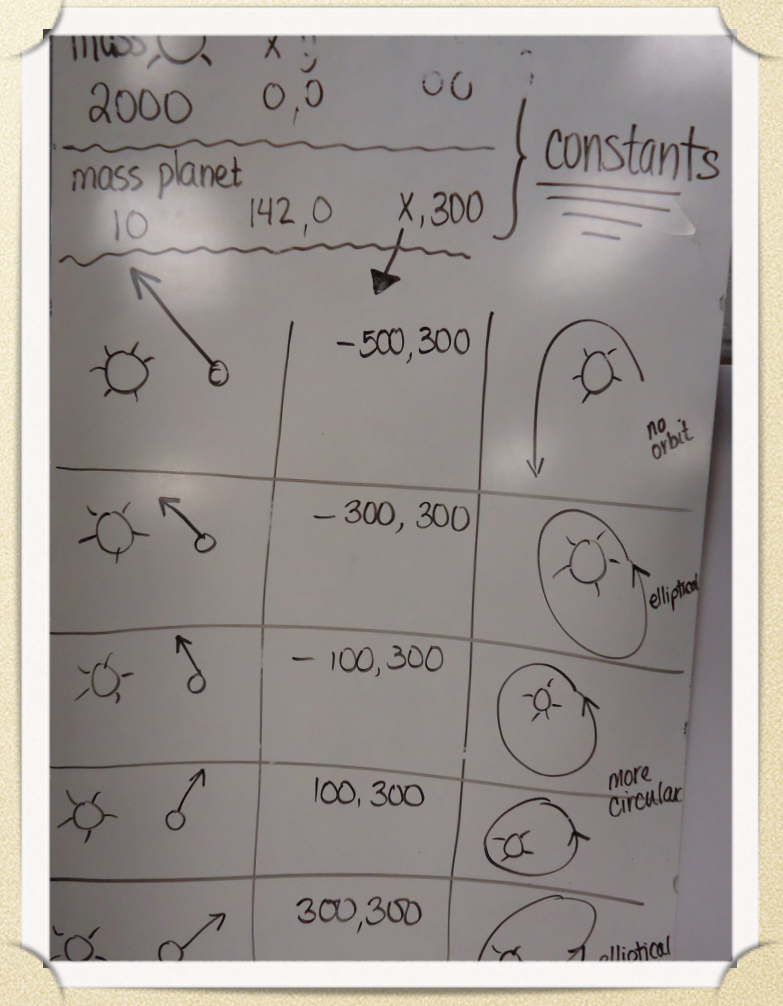
To tackle the reasoning, you want to introduce some model or other information to help students make sense of their patterns.

- In this case, we asked the students to talk about what parameters seemed to influence the orbit
- Mass, velocity, and distance all matter
- Students were reasoning with the force of gravity without knowing it!
- Gives more intuitive feel for subsequent quantitative problems



To assess understanding, students write report using claims, evidence, and reasoning from their notebooks.

- Modeling the process of science
- Encourage students to continue to use the simulation out of class
- Use screen shots as evidence
- Can make measurements off of the screen



There are several resources for you to continue with this idea of CER as a framework for student investigations.

- Read this book
- See our Earth Scientist article — http://www.essp.psu.edu/earth-scientist
- Join PAESTA — it's free and open to non-PA residents
- PAESTA has other CER exercises in ESS