Galileo Educator Network

D1.3 – Moons of Jupiter

(1 hour and 45 minutes + 15 minute Break)

1. Observing Jupiter's Moons (15 minutes)

- Explain how Galileo used the telescope to learn more about objects in our Solar System: ***[slide]***
    - Galileo heard about a Dutch invention of the spy glass that enabled people to look at far-away objects.
    - He obtained the designs and quickly improved them.
    - Galileo was one of the first to aim his spyglass, or telescope, at the heavens, made observations, and recorded his data.
    - Galileo observed the Sun, Moon, and several planets.
    - When Galileo looked at Jupiter through his new telescope he observed a bright ball of light, which he identified to be the planet Jupiter, with star-like objects nicely aligned to the left and right. ***[slide]***
    - Because it was such a remarkable configuration, Galileo returned to it for several nights.
    - We will simulate Galileo's observations in the following investigation.
    - We will analyze the data and use it to study the motion of objects in the Solar System.

  (3 minutes)

- Distribute the ***[Handout D1.3.1 Observing Jupiter – Recording Sheet]*** to each participant.
- Show night 1 and explain that the star-like objects are color-coded for easy identification: red, yellow, blue, and white. ***[slide]***
- Ask each table group to decide who tracks which colored object:
    - If there are 4 participants per table, each participant tracks a different colored object.
    - If there are less than 4 participants at a table, some participants will track two different colored objects (red and white).
- Ask participants to record the position of their colored object for night 1 on the first line from the top, labeled night 1, and continue to nights 2 and 3. ***[4 slides]***

  (5 minutes)

- Ask participants to predict the position of their colored object for night 4 (indicated by a different symbol as used for observations) and then show night 4 and ask participants to record the actual position and compare to their prediction. ***[2 slides]***
- Repeat for nights 5 – 9. ***[10 slides]***
  - Night 7 is a cloudy night; ask participants to interpolate based on observations during nights 6 and 8.

  (7 minutes)

2. Analyzing and Interpreting Jupiter Data (10 minutes)

- Ask participants to work with their group, identify patterns, and describe the data. ***[slide]***
  - Don't try to explain the data!

  (6 minutes)

- Use the ***Numbered Heads*** strategy and ask selected participants to describe the motion of their object and add or emphasize the following points:
  - The colored objects seem to be moving sideways from left to right or right to left.
  - Most of the objects (except for the white object) return to the same place after a certain time.
  - For some of the colored objects (notably the blue and white objects) the amount by which their positions change varies from night to night with larger changes occurring when the object is near Jupiter and smaller changes occurring when the object farther to the left or right from Jupiter.

  (4 minutes)

3. Modeling Jupiter Data (25 minutes)

- Distribute the modeling materials:
  - One large Styrene ball
  - Two small Styrene balls.
  - Three bottle caps
- Ask participants to work with their table group and build a model to help them make sense of the Jupiter data. ***[same slide]***
  - What does the data tell us about the motion of the four objects?
  - Can we build a model that explains the observations including the changes in speed of the 4 objects as they move from left to right and vice versa?

    - What do you think is the nature of these four objects?

  (15 minutes)

- Use the ***Numbered Heads*** strategy and ask a participant from one of the table groups to share their model.
    - Ask other table groups if they have anything to add
    - Add or emphasize the following points:
        - The data supports a model in which the objects go around Jupiter.
        - Because the objects stay with and go around Jupiter, just like our Moon goes around Earth, the objects are likely moons of Jupiter.
        - The slower motion of the objects at the positions farthest to the left and right of Jupiter is in agreement with circular motion.
        - The orbits must be nearly circular because:
            - Jupiter is at the center of the motion (left-right symmetry)
            - The time it takes the objects to go from left to right is similar to the time it takes the object go from right to left, (front-back symmetry).
            - Because the objects orbit Jupiter, just like our Moon orbits Earth, they must be moons of Jupiter.
    - If needed, model the motion of the objects in front of the room:
        - Ask a for a volunteer
        - The volunteer's head represents Jupiter.
        - Position a hula-hoop so that it represents the object's orbit around Jupiter.
        - Use a Styrene ball to represent one of the colored objects.
        - Show how a constant circular motion of the object would appear as a sideways back and forth motion with slower speeds observed at positions farthest to the left or right of Jupiter (due to the line of sight motion towards or away from the observer).
        - Demonstrate the left-right and front-back symmetry and how it would be different if the orbit was highly elliptical.

  (10 minutes)

4. Reflection on the Nature of Science (20 minutes)

- Show the Galileo Video to reflect on the first part of the investigation. ***[slide]***

(4 minutes)

- After the participants have viewed the video, ask selected participants to answer the following questions : ***[slide]***
  - Why did Galileo look at Jupiter?
  - Why did Galileo repeat his observation?
  - What question did Galileo ask?
  - What did Galileo do that helped to answer his question?
- Summarize the answers to these questions by making the point that Galileo was one of the first scientists who set personal and/or religious beliefs aside and gave priority to empirical evidence. ***[slide]***
  - This was the start of modern science as we know it as opposed to the more philosophical approach to science that was common before Galileo's time.
  - An important understanding about the Nature of Science is that scientific knowledge is based on empirical evidence.
  - Another important understanding about the Nature of Science is that new technologies advance scientific knowledge.

(4 minutes)

- Ask participants to briefly discuss with a partner whether Galileo followed the "scientific method" that appears in most text books. ***[slide]***
- After allowing a brief pair discussion, make the following points: ***[slide]***
  - There is no one single step-by-step scientific method.
  - Scientists use a variety of methods to investigate the natural world.
  - Many sciences such as astronomy, earth science, and biological evolution do not use experiments (in which a variable is changed and other variables are controlled), but carefully observe and analyze either distant objects or historical records.
  - In astronomy distant objects provide historical information, because light travels at a constant maximum speed we see distant objects as they were in the past.
  - An important understanding about the Nature of Science is that science investigations use diverse methods and do not always use the same set of procedures to obtain data.

(4 minutes)

- Ask participants to briefly discuss with a partner why scientific knowledge changes. ***[slide]***
- After allowing a brief pair discussion, make the following points: ***[slide]***

- An important aspect of the nature of science that we experienced in this investigation is that scientific knowledge can change.
- Changes are often slow, and can take years, decades, sometimes centuries.
- Changes are always based on data and evidence.
- One of the reasons certain areas of scientific knowledge are changing so quickly right now (brain research, planets around other stars) is that new technologies allow us to collect new evidence.
- This relates to several important understanding about the Nature of Science: ***[slide]***
  - Scientific explanations are subject to revision and improvement in light of new evidence.
  - The certainty and durability of science findings varies.
  - Science findings are frequently revised and/or reinterpreted based on new evidence.

(4 minutes)

- Ask participants to briefly discuss with a partner whether Galileo's work involved creativity? ***[slide]***
- After allowing a brief pair discussion, make the following points: ***[slide]***
  - Science is a human endeavor which includes human characteristics such as persistence, bias, and creativity.
  - Creativity is an important part of doing science.
  - Building models and hypotheses are creative processes that require "thinking outside the box": Galileo allowed himself to consider models beyond the then accepted Geocentric Model.
  - We cannot prove a hypothesis to be correct; we can only disprove it.
  - It is therefore important to be creative and come up with as many hypotheses as possible and test them all. The hypotheses that survive the test of time (based on evidence) become part of scientific theories (they don't become scientific theories!)
  - An important understanding about the Nature of Science is that scientists and engineers rely on human qualities such as persistence, precision, reasoning, logic, imagination and creativity.

(4 minutes)

Break (15 minutes)

5. Data Analysis (35 minutes)

- Explain that we are now continuing this investigation and will analyze the data in more detail to learn more about the motions of the four moons that Galileo discovered and about the motion of objects in the Solar System in general.
    - We will assume circular motion.
- Ask participants to discuss with their table group how the data can be used to determine the speed of each moon..

  (5 minutes)

- Use the ***Numbered Heads*** strategy and ask a participant from one of the table groups to share and add or emphasize the following points: ***[slide]***
    - We can use the data to determine (and compare) how long it takes each moon to complete an orbit
        - Unit = day
    - We can use the data to determine (and compare) the distance to Jupiter (or orbital radius) for each moon.
        - We need to measure the moons furthest separation form Jupiter (to the left or right).
        - We need to know what the scale: the numbers 1 and 2 represent 1 million and 2 million km.
        - Unit = million km
    - We can use the data to determine and compare the speed for each moon.
        - When we know the distance for each moon we can calculate the circumference or the length of each orbit.
            - Unit = million km
        - When we know the length of each orbit we can calculate the speed of each moon by dividing the length of the orbit by the time it takes the moon to complete it
        - Unit = million km / day

  (5 minutes)

- Distribute ***[HO D1.3.2 – Moons of Jupiter Data Analysis]***
- Explain that participants may use part 1 of this handout to record the calculations for their colored moon.
    - Part 2 will be used to record the results for all four moons based on the calculations of the whole group.
- Ask participants to individually complete the data analysis for their moon only!

    - Create a large chart (landscape) on chart paper with color down the left and orbital period, distance, length of orbit, speed, and name across the top.

  (5 minutes)

- Ask selected participants to report their data for the red moon, calculate averages and range, record on chart, and add the names.
    - Participants should record the averages and range in part 2 of the handout.
- Repeat for the yellow, blue, and white moons.

  (15 minutes)

- Ask participants to use the graph paper, on the second page of the handout, to graph the orbital speed versus distance for Jupiter's moons and describe what the graph tells them. ***[slide]***
- Ask selected participants to share and add or emphasize the following points: ***[same slide]***
    - The moons have different speeds, which decrease with distance.
    - The decrease is not linear (in fact it is 1/ sqrt (r))
- Explain that this data could further be used to discuss Kepler's Laws.

  (5 minutes)