A Six Lesson Unit for Grade 2 on

Gravity and Motion in Our Solar System

(Part of a full six-week PYP unit entitled “The Solar System”)

Developed by Daniel Vimont

George Mason University – FAST TRAIN Program – EDUC 514

Submitted on November 15, 2009

Unit Overview

Unit Title: "Gravity and Motion in our Solar System"
Grade Level: Grade 2
Subject/Topic Areas: Physics & Astronomy
Key Words: gravity, force, orbit, weightlessness, energy, star, planet, g-force, velocity
Designed By: Daniel Vimont
Time Frame: 2 weeks (out of a full 6 week PYP unit)
School: International School of Tianjin

Brief Summary of the Unit:

This unit serves as a component of a larger PYP unit entitled "The Solar System" in which the central idea includes the concept of how gravity governs the movements of the components of the Solar System. In the previous school year, it was evident that some of the fundamental ideas of how gravity works were not being fully grasped by the end of the PYP unit, so this gravity sub-unit represents an almost complete reworking of the gravity-oriented lessons of the PYP unit with the goal of improving retention and understanding of basic gravity concepts. The later lessons of this unit build upon the scaffolding of concepts presented in the earlier lessons, and the subject matter of the later lessons allows for review of earlier-presented ideas, to aid in assuring retention of fundamental concepts.

In addition to the six gravity and motion oriented lessons presented in this paper, additional formative assessment tasks may be included in the overall Solar System unit to confirm and reinforce students' understanding of gravity: (1) One of the unit's paragraph writing sessions can be devoted to writing about a specific facet of gravity. (2) Small groups can make brief presentations demonstrating a facet of gravity. (3) In their final written and oral unit presentations, students will be strongly encouraged to include information about their chosen planet or moon's orbital path and the force of gravity (relative to Earth's gravity) exerted by their chosen body.

Essential questions:

- Is there gravity on the Moon and on the other planets?
- Is there any place where there is no gravity?
- Why does the pull of gravity feel weaker or stronger in different places in the Solar System?
- How do planets and moons stay in orbit?
- Do objects of different mass fall at different rates?
- Why do astronauts out in space feel no gravity?
- What notable effects does the Moon's gravity have on the Earth?

Lesson 1: A Hands-on Introduction to Newton's First Law of Motion

I. Objectives:

- Students will be able to explain (orally, in drawings, and/or in writing) how Newton's First Law of Motion works in regard to their own hands-on experiences with inertia.
- Virginia Standards of Learning:
  4.2 -- *The student will investigate and understand characteristics … of moving objects.*
  6.8 -- *The student will investigate and understand the organization of the solar system and the relationships among the various bodies that comprise it. Key concepts include ... the role of gravity.*
  PS.10 -- *The student will investigate and understand scientific principles and technological applications of … motion. Key concepts include … Newton's laws of motion.*

II. Materials:

- Flip Camera, or equivalent digital video camera
- Interactive whiteboard
- Masking tape or chalk
- A sturdy plastic toy truck
- Brick or similar heavy object
- Students' unit journals (for pictorial and written assessments)

III. Procedures for Learning Activities:

Hands-on motion experience #1: The first part of the lesson takes place in P.E. class. By making prior arrangements with the P.E. teacher, the students will directly experience inertia by doing (either in the gym or outdoors) a "running stop" exercise (Cislunar, 2009, #1). The running stop exercise may take place either in the gym or on an outdoor running surface. Prior to the lesson, a starting point, two midpoints at 10 and 20 feet, and an endpoint at 25 feet are marked out with chalk or tape, or already-existing markings (marking those approximate distances) on the gym floor are used.

Students are told that the class's study of motion (as part of the Solar System unit) is about to begin, and that they are going to be using their bodies to experience something called "inertia" firsthand. All the proceedings are video-recorded by a teacher (or by capable students who take turns making recordings). First, each student runs from the starting point and over the endpoint without slowing down or stopping. On their second run, each student runs from the starting point, but comes to a complete and sudden stop at the 10 foot marker. They do similar running and stopping at the 20 foot point and the 25 foot point. After the activity is done, teacher and students briefly discuss the experience of trying to stop at a certain point while in motion. Was it easier to stop on the endpoint (after running 5 feet) than it was to stop on one of the midpoints (after running 10 feet)? Teacher can also ask leading questions such as "When your body is in motion, and you try to stop it, what does your body tend to do?" to lead directly into the classroom study of Newton's First Law of Motion.

Hands-on motion experience #2: Back in the classroom (either later in the day or the next day), the motion lesson continues with an "animal crash" exercise (Cislunar, 2009, #2). A brick is placed in an appropriate place on the floor, and one student volunteer at a time places a stuffed animal in a toy dump truck and rolls the truck to crash into the brick from a few feet away. The truck should stop, but the stuffed animal should go flying.

Discussion: The discussion begins with teacher showing a video of one or two of the students performing the "running stop" exercise, followed by a video (prepared beforehand) of the stuffed animal flying out of the toy truck. Students are asked to describe the similarities between their bodies in the P.E. exercise and the stuffed animal in the crash exercise. They are asked to create general statements about a body in motion, and the teacher writes their statements onto a whiteboard. Then, on the interactive whiteboard the teacher brings up a picture of Isaac Newton, tells a little about him, and explains that he made a very famous statement about bodies in motion that relate directly to our "running stop" and "animal crash" activities. His "First Law of Motion" is presented in terms such as "something that is moving will keep on moving until some opposing force acts upon it". He used one word to refer to this: "Inertia".

IV. Assessment:

Written and oral assessment: Each student makes a drawing and writes a few sentences (with the length and complexity of writing dependent upon ESL status) explaining the "running stop" activity and/or the "animal crash" and how it demonstrates the principle of inertia. The words "inertia" and the phrase "Newton's First Law of Motion" and its definition are left up on the white board as reminders for spelling. Audio recordings are then made of the students reading these statements and having a brief discussion with the teacher about Newton's First Law.

V. Differentiation:

Following the norm in this class, very "early readiness" ESL students (if any remain in that status late in the year when this unit will take place), will be assisted throughout by another student who shares their first language. This will be particularly important in the audio recording for the oral assessment, in which case a student may need to serve a translator role. ESL students will be invited to do more of their explaining of the lesson's concepts with pictures and less with words, depending up their ability.

More advanced students will be engaged in deeper discussions about inertia with the teacher during the audio recorded oral assessment. They will also be invited to do more extensive write-ups in their pictorial and written assessment, perhaps giving other real-world examples that they are aware of that demonstrate inertia. The next section explains an extension that might particularly be appropriate for more advanced students.

VI. IT Extension:

If arrangements can be made with the IT instructor, students can make video presentations with their own explanations of Newton's First Law and inertia. They can use a combination of still photos and videos from the two activities along with scanned images of their drawings as the basis for a short video presentation, with a voiceover consisting of them reading their written assessment. This can be done either with Windows Movie Maker or by using the facilities on the Voicethread website.

References

Cislunar Aerospace, Inc. (2009, #1). *The K-8 Aeronautics Internet Textbook:* ***Running Stop***. Retrieved on October 22, 2009 from: http://wings.avkids.com/Curriculums/Forces_Motion/running_stop_howto.html

Cislunar Aerospace, Inc. (2009, #2). *The K-8 Aeronautics Internet Textbook:* ***Animal Crash***. Retrieved on October 22, 2009 from: http://wings.avkids.com/Curriculums/Forces_Motion/animal_howto.html

<u>Lesson 2</u>: Observing How Gravity Works

I. <u>Objectives</u>:

- Students will be able to explain, pictorially and in writing, (1) that gravity is the force that pulls things toward the Earth, the Moon, the Sun, and the other planets, (2) that the weight of an object does not affect the speed at which it falls, and (3) that air resistance can affect the speed at which very light objects fall.
- Virginia Standards of Learning:
  *<u>6.8</u> -- The student will investigate and understand the organization of the solar system and the relationships among the various bodies that comprise it. Key concepts include ... the role of **gravity**.*

II. <u>Materials</u>:

- Flip Camera, or equivalent digital video camera
- Interactive whiteboard
- "What is Gravity?" video: http://ksnn.larc.nasa.gov/k2/s_whatGravity_v.html
- "Feather & hammer drop on Moon" video: http://www.youtube.com/watch?v=5C5_dOEyAfk
- Pre-recorded videos of the three experiments in this lesson being performed by teacher
- 24 worksheets on clipboards with pencils (one for each student in both Grade 2 classes)
- 12 pairs of marbles (each pair consisting of one large, one small)
- 12 rulers
- 12 large binders (for use as ramps)
- a feather and a weightier object (preferably a plastic hammer or small real hammer)
- Students' unit journals (for pictorial and written assessments)

III. <u>Procedures for Learning Activities</u>:

Students gather for lesson on the carpet area, bringing their unit binders with them (which will serve as an inclined plane in one of the lesson's experiments). Teacher begins lesson with dramatic flair by dropping a pencil (or some other object) from her outstretched hand onto the floor. Teacher asks, "What just happened?" to elicit the answer that the object fell. This question is followed up by "What made it happen?" and/or "Why did it happen?" The presumption is that many of the children will offer "gravity" as an answer. This can be followed by the open (and as yet unanswered by scientists) question, "What is gravity?" This can lead in to the brief children's video "What is Gravity?" (http://ksnn.larc.nasa.gov/k2/s_whatGravity_v.html), which gives an entertaining overview of what gravity ***does*** (as a character unsuccessfully tries to juggle three balls), but does not explain what it ***is***. After the video, a brief discussion is engaged in to assure that students understood the main ideas of the video. Teacher can accentuate that scientists have still not figured out exactly what gravity is.

Teacher then models the two hands-on experiments: (1) "Pencil/Shoe Drop" – simultaneous dropping of a pencil and a student's shoe from the same height to see whether one will hit the ground before the other, and (2) "Marble Roll" -- rolling of two marbles (one large, one small) down an inclined plane (unit binder) to see which rolls off first. The teacher models both experiments, using two equivalent objects (i.e., two shoes and two same-sized marbles), so as to not give away the result when differing objects are dropped or rolled. For the second experiment, a ruler is used as the "starting gate" for the two marbles, with the ruler quickly raised to release the marbles simultaneously.

Students are paired up and given a clipboard and pencil with worksheet attached. Before they are provided further materials, they are asked to fill out the "I predict" sections for both experiments, in which they predict which object will hit the ground or roll off the binder first, or whether both will arrive at the same time. Each pair of students is then provided with marbles and ruler (for "Marble Roll"), and they perform their experiments in pairs, taking turns playing the role of experimenter and observer (with the observer role being the one requiring refined powers of observation). Teacher or teaching assistant records some of the experiments using the Flip camera. After they have performed each experiment a few times, they record their observations in the "I observe" section of the worksheet for each experiment.

The entire class should come back together for discussion of the observations. *From the past year's experience with this particular experiment, some students might be expected to declare that the shoe hit the ground first in the first experiment.* As an aid to more exacting experimentation and observation, some of the student experiments should have been recorded with the Flip camera for "instant replay" in slow-motion on the interactive whiteboard. (To provide for possible technical difficulties with this, there should be a "canned" video already prepared with the teacher doing both experiments, which can be viewed in slow motion.) After slow-motion videos have been viewed and a brief group discussion has taken place, each student will fill out the "I conclude" section of their worksheet. Teacher then leads class in coming up with a general statement about falling objects based upon the observations and conclusions students have written (e.g., "All objects fall to the ground at the same speed no matter how much they weigh").

Teacher then selects a few volunteer students to conduct a third hands-on experiment in front of the class: a "Feather Drop" – the simultaneous dropping of a feather and a plastic (or small real) hammer. The drop is repeated three or four times by volunteers, and the final discussion centers around inferring the reason that the hammer hits the ground faster than the feather. After it is agreed upon that air resistance made the feather take longer to fall, teacher offers that, in order for our class's general statement about falling objects to hold true for a feather and a hammer, we would have to find a place to drop them where there is no air. Teacher shows the video of an Apollo 15 astronaut performing just such an experiment on the Moon, where there is no air (http://www.youtube.com/watch?v=5C5_dOEyAfk).

IV. Assessment:

Students draw and/or write entries for the following in their unit journals: (1) a verbal and/or pictorial explanation of what the gravity of the Earth and Moon does to objects; (2) a writing out of the class's "general statement" about falling objects, along with picture illustrating what the general statement says; (3) a written and/or pictorial explanation of why the feather drop experiment works differently on Earth than on the Moon.

If time and resources allow, individual interviews can be recorded on video with students discussing their unit journal entries. These may be posted to the class website.

V. Differentiation:

ESL students will be permitted and expected to rely more heavily on pictorial explanations, depending upon the abilities of the individual. As required, translations may be provided by other students who share the first language of ESL students, and the ESL specialist teacher may be available on a push-in basis to assist during this lesson.

Advanced students can engage in the discussion outlined in the following "extension".

VI. Extension:

Given that some of the students may well have reported that the shoe hit the ground before the pencil in the "Pencil/Shoe Drop" experiment, this affords an opportunity to discuss how bias in the minds of experimenters can sometimes affect the perceptions of the experimenters, or skew the way they interpret the data or observations. Given that most second graders are very keen on getting the “right answer”, this situation also affords an opportunity to discuss that, in a scientific experiment, making correct observations is much more important than making a correct prediction. In fact, the main reason we make scientific predictions is to give focus to our observations, and not necessarily to make the “right” prediction. These concepts may be discussed (optionally recorded in audio or video format), pictorially represented, and written about.

Lesson 3: Motion and Gravity Working Together – How Orbits Work

I. Objectives:

- Students will be able to explain orally and in writing, with the aid of their own pictures or diagrams, why the Moon orbits the Earth, neither falling into the Earth nor sailing off into space.
- Virginia Standards of Learning:
  PH.5 -- The student will investigate and understand the interrelationships among mass, distance, force, and time through mathematical and experimental processes. Key concepts include Newton's laws of motion; gravitation; and ***planetary motion****.*

II. Materials:

- Flip Camera, or equivalent digital video camera
- Interactive whiteboard
- Computers (9 of them) in the Grade 2 shared room (between the classrooms)
- Virtual manipulative – shoot a cannonball into orbit: http://spaceplace.nasa.gov/en/kids/orbits1.shtml or http://galileoandeinstein.physics.virginia.edu/more_stuff/flashlets/NewtMtn/NewtMtn.html
- Students' unit journals (for pictorial and written assessments)

III. Procedures for Learning Activities:

Teacher starts out lesson holding the class's blow-up beach-ball-style model of the Moon, which is normally hanging from the ceiling on a string throughout the Solar System unit. She reminds the class of the last gravity lesson, in which we observed things falling to the Earth due to the Earth's gravity. Given what we observed, shouldn't we expect the Moon to simply fall into the Earth? [Teacher drops the Moon and it falls to the ground.] On the other hand, we know that the Moon is moving around the Earth (established in a previous lesson in the broader Solar System unit), so what keeps the Moon from flying off into space? [Here the teacher takes the blow-up Moon model, which has a string attached to it, and twirls it around here head. "My head is the Earth. The string represents gravity, 'holding on' to the Moon. If I were to shut gravity off, what would happen?" The class does a count-down starting from "5", and on zero, the teacher releases the Moon, which goes flying across the room. Without gravity, the Moon *would* sail off into space.

Teacher now brings up a "thought experiment" of Newton's in which he imagined a huge cannon on an incredibly high mountain, and brings up a corresponding virtual manipulative (http://spaceplace.nasa.gov/en/kids/orbits1.shtml) on the interactive whiteboard.

Shoot a Cannonball into Orbit!

This Is How Orbits Work!

Teacher models usage of the virtual manipulative (select "Amount of gunpowder" on left, and click "Fire" on right). Students are placed in groups of three and sent to the shared room computers (on which browsers have already been directed to this website) for the groups of three to take turns trying out various "amounts of gunpowder". (The selection of "three bags" or "four bags" sends the cannonball into orbit; the selection of fewer sends the cannonball crashing into the Earth, and the selection of "five bags" sends the cannonball flying into space.)

Class reconvenes on the carpet and reviews the chart that is further down on the webpage containing the "shoot a cannonball" virtual manipulative.

Amount of Gunpowder	What Happens
2 bags of gunpowder:	Cannonball goes faster and gets farther before gravity pulls it back to Earth.
3 bags of gunpowder:	Cannonball is going so fast that it falls all the way around the world. It is in orbit!
4 bags of gunpowder:	Cannonball orbits Earth again, but goes even higher at the peak of its arc.
5 bags of gunpowder:	Cannonball is going so fast it completely escapes Earth's gravity and heads out into space, maybe to an asteroid or Mars or Jupiter!

By combining the reading of the words on the chart and replaying the virtual manipulative, teacher makes it clear that the cannonball and the Moon are in effect falling around the Earth, but the motion of the cannonball and the Moon causes the objects to "miss" hitting the Earth. Teacher introduces the term "velocity". Given the right velocity (a "goldilocks" velocity – just right), the cannon and Moon neither crash down to Earth (too little velocity) nor sail out into space (too great a velocity). Students are encouraged to do like Newton and conduct their own "thought experiment", thinking back to the "animal crash" experiment of the first gravity lesson. Imagine doing the crash of the truck with such a great velocity that the stuffed animal (1) went a very long way before crashing to Earth, (2) went so fast that it went into orbit, and (3) went so very fast that it shot out into space away from the Earth.

IV. <u>Assessment</u>:

In their unit journals, students are to draw and (to extent of ability) write out an explanation of their "thought experiment", either with the "animal crash" scenario or the Newtonian cannonball scenario. Three drawings show (1) insufficient velocity to achieve orbit, (2) orbit achieved, (3) sailing off into space. Students are asked to include an explanation of which drawing shows a situation similar to the Moon in relation to the Earth. To extent of ability, students should explain in their own words how velocity and gravity work together to make an orbit happen. (E.g., "A high velocity keeps the ball from falling to Earth, but gravity keeps it from going into space.")

V. <u>Differentiation</u>:

More advanced students can further explore the webpage containing the virtual manipulative and write a paragraph discussing Sir Isaac Newton and his thought experiment. ESL students will again be anticipated to rely more heavily on pictorial explanations than on verbal explanations.

VI. <u>Extension</u>:

Watch video of images taken in Earth's orbit: (http://www.youtube.com/watch?v=LURGnbcTVK4). Do video interviews with students asking them if they would like to make a trip to be in orbit some day.

<u>Lesson 4</u>: Your weight depends on where you are in the Solar System

I. <u>Objectives</u>:

- Students will be able to describe, in words and/or pictures, the various situations in which weightlessness is experienced, contrasting them with situations in which an object or a person is weighted down. They will also graphically show that their weight would differ on the other planets in the Solar System.
- Virginia Standards of Learning:
  <u>6.8</u> -- The student will investigate and understand the organization of the solar system and the relationships among the various bodies that comprise it. Key concepts include ... the ***role of gravity.***

II. <u>Materials</u>:

- Flip Camera, or equivalent digital video camera
- Interactive whiteboard
- Virtual manipulative – cannonball in orbit: http://spaceplace.nasa.gov/en/kids/orbits1.shtml
- Webpage "Are you really weightless in orbit?": http://www.nasm.si.edu/exhibitions/gal109/NEWHTF/HTF611A.HTM
- Discovery video, "The Moon: Gravity" (http://player.discoveryeducation.com/index.cfm?guidAssetId=4E9C69C5-6557-424D-9D40-23E68AB5D970&blnFromSearch=1&productcode=US)
- Pictures and videos of astronauts in International Space Station
- Students' Unit Journals (for pictorial and written assessments)

III. <u>Procedures for Learning Activities</u>:

Teacher begins lesson by asking students about their experiences with falling or the feeling of falling: on amusement park rides, in a rapidly descending plane, etc. What did it feel like? How long did it last? Teacher shows brief video of skydiver in freefall, explaining that while falling, a skydiver feels weightless. Recalling back to the previous lesson on orbit, what do students suppose it feels like to be in orbit – do people feel weight, or are they weightless? Teacher show some pictures and brief videos of astronauts in the International Space Station. Then teacher returns to the virtual manipulative of the cannonball in orbit from the previous lesson. Teacher puts the cannonball in orbit, and uses the motion of the cannonball to point out that an orbit can be conceived of as a perpetual state of falling, or free fall. The following picture (from http://www.nasm.si.edu/exhibitions/gal109/NEWHTF/HTF611A.HTM) is shown

alongside of the orbiting cannonball to illustrate to students that, if you were standing very high up on a ladder, you would still feel weight, since you would not be orbiting (i.e., you would not be in freefall). Teacher emphasizes that what is required to feel weight is to be in a fixed position relative to a large body like the Earth.

Teacher reruns the video from the "animal crash" experiment in the first lesson, and freezes the video on a frame in which the stuffed animal is flying through the air. At that moment, is the stuffed animal weighted or weightless? Teacher emphasizes that it too is in freefall. (Sketches, with labels, of all of these freefall situations are made up on the whiteboard for later reference by students when they do their drawings and write-ups of the lesson's concepts.)

What about the Moon? Is there gravity on the Moon? Teacher briefly shows some videos of Apollo astronauts walking around on the Moon (and possibly reruns the "feather and hammer drop" video shown in the second lesson). The astronauts are not flying off into space, but do they appear to be heavier or lighter than we are here on Earth? (Notice, when they jump up, how long it takes for them to come back to the ground. In fact, we are 6 times as heavy on the Earth as we would be on the Moon.) Student volunteers are invited to divide their weight by 6 and say how much they would weigh on the Moon. To reinforce these ideas, the brief Discovery video “The Moon: Gravity” (http://player.discoveryeducation.com/index.cfm?guidAssetId=4E9C69C5-6557-424D-9D40-3E68AB5D970&blnFromSearch=1&productcode=US) is viewed on the interactive whiteboard.

Teacher then shows a website that students will be using to calculate their weight on the other planets of the Solar System (http://www.exploratorium.edu/ronh/weight/). Students are sent to the computers in the shared room in groups of three to calculate and print out their weight calculations. The TA may need to assist with the printing. (Note: print only the first two pages of the weight calculation webpage to save paper.)

IV. Assessment:

Students will be supplied with a worksheet set up with axes for creating a bar graph of their weight on the different planets and on the Moon. Beneath the graph are items for them to complete: “I would weigh the least on ______. I would weigh the most on _______. On ______ I would weigh almost the same as I do on Earth.”

Additionally, in their unit journals students will, through pictures and/or words, explain in which situations they would feel weightless.

V. Differentiation:

Beginning ESL students will again be anticipated to rely more heavily on pictorial explanations than on verbal explanations. Advanced students can be encouraged to provide more detailed written and diagrammatic explanations as to why weightlessness occurs when astronauts are in orbit.

VI. Extension:

If students already have appropriate computer skills, they may also create their bar graphs using a spreadsheet computer program. For optional viewing and discussing, an interesting video called “Zero Gravity Classroom” (showing a group of science teachers experiencing weightlessness in NASA’s weightlessness-training aircraft) can be shown: http://www.youtube.com/watch?v=phNOGnTnXy4

Lesson 5: The Orbits of the Planets of Our Solar System

I. Objectives:

- Students will be able to explain how their own experiences working with angular momentum illustrate that the planets closer to the sun move faster than those further from the sun.
- Virginia Standards of Learning:
  *PH.5 -- The student will investigate and understand the interrelationships among mass, distance, force, and time through mathematical and experimental processes. Key concepts include Newton's laws of motion; gravitation; and **planetary motion**.*

II. Materials:

- Flip Camera, or equivalent digital video camera
- Interactive whiteboard
- A drinking straw, cut in half
- A two to three foot string
- A washer or similar weight, tied to string
- A figure skating video demonstrating faster spin as arms and legs are brought closer, such as this one: http://www.youtube.com/watch?v=AQLtcEAG9v0
- Web-based planetary orbit animations, including:
  http://astro.unl.edu/naap/pos/animations/kepler.swf
  http://mistupid.com/astronomy/orbits.htm
  http://www.cfa.harvard.edu/afoe/simulation/e2.html
  http://www.cfa.harvard.edu/afoe/simulation/e3.html

III. Procedures for Learning Activities:

To provide a brief review of all concepts covered so far, the Discovery video, "Gravity, Orbiting, Inertia, and Weightlessness" is viewed and discussed (http://player.discoveryeducation.com/index.cfm?guidAssetId=09837375-C032-4C6D-880F-428AB07A7283&blnFromSearch=1&productcode=US).

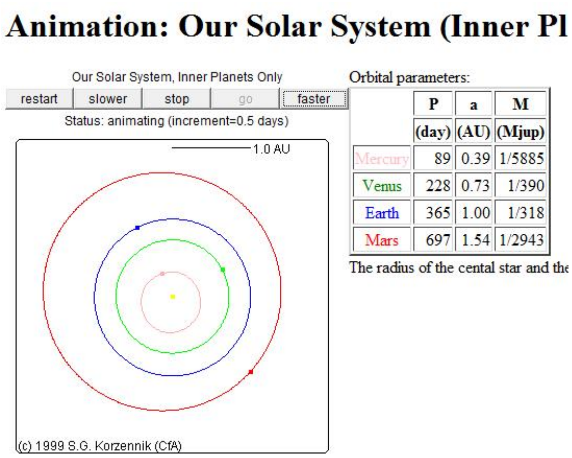
Teacher explains that it today's lesson we will take a closer look at orbits. Student volunteers are sought out to name the eight planets in order of distance to Sun. Students are asked to guess/predict which planets move more slowly around the sun and which move at a greater speed around the Sun.

Teacher states that, to help us make sense of the velocity of the planets in their orbits around the Sun, we will do an exercise with something that does not involve gravity and orbits, but that in this case works in a similar way. Since this exercise involves twirling an object on a string (and the inherent dangers of that), it may be best for the teacher to do the activity, or for teacher to get a very responsible and coordinated volunteer student to do it, and to be sure that appropriate eye-protective covering is worn.

The person performing the exercise feeds the non-weighted end of the string through the straw so that the non-weighted end is only just protruding from the straw. Taking hold of the non-weighted end with one hand, the person takes the straw and begins to twirl the weighted end at the full length of the string overhead. Continuing with the twirling motion, the person begins to pull down on the end of the string in their hand, thus shortening the radius of the twirling string, resulting in the speed of the twirling to noticeably increase. This exercise is repeated a few times.

Teacher explains that the weight on the end of the string is not in orbit, but it is behaving similar to the way orbiting objects do with regard to its speed. To further illustrate the concept, the video of a figure-skater executing a spin is shown (http://www.youtube.com/watch?v=AQLtcEAG9v0); as she pulls her arms and legs in close to her body, the speed of her spin greatly increases. Again, the skater's arms and legs are not in orbit, but they are behaving similar to the way that orbiting objects behave.

Students are now asked to consider revising their original predictions regarding which planets move more slowly around the sun and which move at a greater speed around the Sun. Finally, one or more of the web-based animations showing the relative speed of the planetary orbits is brought upon the interactive whiteboard (see links above). Class discussion focuses on interpreting what is shown in the animations, which clearly show the inner planets moving at greater velocity than the outer planets.



IV. <u>Assessment</u>:

A video is made of each student being briefly interviewed about how the angular momentum exercise (with the straw and weighted string) illustrates how the planets nearer to the sun move faster than those further away. Students will be recorded standing in front of the interactive whiteboard, so they may reference and point to the web-based animation of the planets' orbits during their explanation. Videos will be posted to the class website and will be included in each student's digital portfolio.

In the final project of the Solar System unit (which allows students to do deeper research on a planet of their choice), students will be expected to include information about the length of orbit of their chosen planet.

V. <u>Differentiation</u>:

As in previous experiences doing interview-type assessments of Grade 2 students, it is expected that more advanced students will need less prompting and leading through the concepts, while those students in a stage of early readiness may well need more prompting to explain the concepts. Some ESL students may need assistive translation from their fellow students.

Lesson 6: The Effect of the Moon's Gravity on the Earth

I. **Objectives**:

- Students will be able to describe, in words and pictures, the effect of the Moon's gravity on the Earth's oceans.
- Virginia Standards of Learning:
  3.8 -- The student will investigate and understand basic patterns and cycles occurring in nature … [including] ***tides****.*
  6.8 -- The student will investigate and understand the organization of the solar system and the relationships among the various bodies that comprise it. Key concepts include ... the ***cause of tides****.*
  ES.4 -- The student will investigate and understand the characteristics of the Earth and the solar system. Key concepts include ... sun-Earth-moon relationships (seasons, ***tides****, and eclipses).*

II. **Materials**:

- Flip Camera, or equivalent digital video camera
- Interactive whiteboard
- Discover video, "Tides": http://player.discoveryeducation.com/index.cfm?guidAssetId=58229B2B-B806-415F-A8D5-D174BB082381
- Time-lapse video showing incoming/outgoing tide: http://www.metacafe.com/watch/828233/time_lapse_tide_changes_at_10_000_times_normal_speed/
- Web-based animations showing the Earth and Moon orbiting one another (i.e., showing slight wobble of Earth due to Moon's gravity):
  Animated GIF file: http://library.thinkquest.org/29033/begin/barycenter.gif
  Animation closer to scale: http://www.orbitsimulator.com/gravity/articles/barycenter.html
  Animation to scale: http://calgary.rasc.ca/barycenter.htm

III. **Procedures for Learning Activities**:

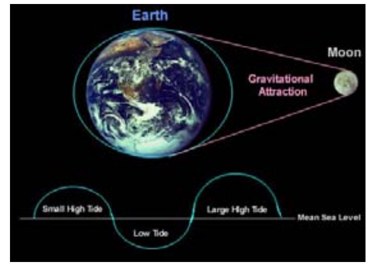
Teacher explains that so far in the unit, some of the presentations have described how the Moon orbits the Earth, and this is the common way we think of the relation between the Earth and the Moon. But to get a better idea of the true way the Earth and Moon interact with each other, teacher requests a volunteer to help her demonstrate. Teacher is the Earth, and student is the Moon. They each cross arms and join hands and student (Moon) is asked to move in an "orbit" around the teacher (Earth). The demonstration should show that the teacher (Earth) is made to move to adjust to the movements of the student (Moon), even though the "Earth" is much bigger than the "Moon".

Teacher then explains that gravity is a two-way force: not only does the Earth attract and affect the movements of the Moon, but the Moon attracts and affects the movements of the Earth (to a much lesser extent). Animations are shown on the interactive whiteboard (see links above) that show the "wobble" of the Earth caused by the Moon, as the two orbit one another.

Now teacher says that we will make a leap to something completely different, and uses interactive whiteboard to show time-lapse video of incoming and outgoing tides. Students are asked whether they know what is happening here. Brief discussion takes place on tides, and the fact that, in most places in the world, the tide comes in (water level at the coast rises) and goes out (water level lowers) twice a day. Teacher asks if anybody knows or wants to guess what causes the tides?

To offer a very rough illustration, teacher takes a full cup of water, and with one hand repeats the "orbit" demonstration with the student as the Moon. The water in the cup will slosh over the rim of the cup as the teacher is jostled by the "orbiting" student. Teacher poses the question again: What causes the tides?

Discussion follows about how the Moon causes most of the tidal phenomena on the Earth. Images (e.g., http://www.this-magic-sea.com/IMAGES/TIDE.JPG) are displayed on the interactive whiteboard, and teacher explains how the Moon's gravity causes the tide to rise on the side of the Earth facing the Moon, and how the "wobble" of the Earth caused by the Moon (revisit the animations shown earlier, if necessary) in turn causes the tide to rise on the opposite side of the Earth (due to inertia); this gives roughly two tidal sequences per day.



For reiteration of these ideas, students may be shown the brief Discovery Streaming video, "Tides" (http://player.discoveryeducation.com/index.cfm?guidAssetId=58229B2B-B806-415F-A8D5-D174BB082381). Note importantly that this video makes an incorrect statement regarding the cause of the high tide on the side of the Earth opposite the Moon. (It incorrectly states that the far side of the Earth's surface is warped by the Moon's gravity to cause the tidal effect!)

IV. <u>Assessment</u>:

Students are asked to draw diagrams in their unit journals showing the Earth, Moon, and tides. Depending upon language ability, they are asked to write a paragraph describing how the Moon causes the tides.

V. <u>Differentiation</u>:

ESL students will again be anticipated to rely more heavily on pictorial explanations than on verbal explanations. Advanced students can be encouraged to provide more detailed written and diagrammatic explanations as to how inertia causes the tide on the side of the Earth facing away from the Moon.

<u>References</u>

Comins, N. and Kaufmann, W. (2008). *Discovering the Universe: Tides* (p. 172-173). New York: W.H. Freeman and Co.

NOAA Ocean Service Education (2009). *Tides and Water Levels: What Causes Tides?* Retrieved on October 31, 2009 from: http://oceanservice.noaa.gov/education/kits/tides/tides02_cause.html