Pre-assessment for the Moon's Phases and Origin

Part 1

a. In January, the curriculum for sixth grade calls for students to focus on astronomy. Astronomy will focus on our solar system with an aside to the theories of how the universe was formed. One of the concepts to be taught in this unit is the moon. Two topics to be studied under this concept are the phases of the moon and the moon's origin. This research paper will explore not only how the students perceive these two topics, but will also explore the implications.

The moon travels through 8 phases in the course of about 28 days (the actual time is 27 days, 4 hours and 43 minutes). The first phase is the new moon, which is not visible in the sky. The second phase is the waxing crescent where the moon is partly illuminated. The third phase sees the moon one-half illuminated by the sun and is called the first quarter moon. The fourth phase, known as the waxing gibbous shows the moon to be more than one-half illuminated which leads into the full moon or fifth phase. After the full moon one sees the cycle reverse that is the moon becomes less illuminated. The waning gibbous is the sixth phase of the moon and is more than half illuminated. The seventh phase of the moon is known as the last quarter moon where one-half of the moon is visible in the night sky. The last phase of the moon is the waning crescent where less than one half of the moon is illuminated. The cycle than begins again.

The question becomes how does this cycle occur? What makes the phases of the moon? Many people would say that the earth's shadow is the cause for the phases of the moon. Let's look at some of the research to find out if this is true or whether there is another reason that causes the phases of the moon.

The moon rotates at exactly the same rate as it orbits the earth. It takes the sun 24 hours from rising to rising here on earth while it takes 30 days from rising to rising on the moon. Although the earth revolves around the sun in a fixed elliptical orbit, the moon's orbit can vary by five degrees above or below the earth's orbit and therefore its orbit is not on the same plane as the earth's. As a result, the earth's shadow does not have an effect on the phases of the moon. The moon is then capable of traveling around the earth while being illuminated by the sun. If we begin with the phase of the new moon, we see that the moon lies between the earth and the sun. The moon is not visible to us in the sky. As the moon moves around the earth we begin to see the crescent of the moon, followed by the first quarter, the waxing gibbous until it is furthest from the sun, which is located on the opposite side of the earth (Comins, p.36). At this point, the moon is fully illuminated by the sun. If one thought that the earth's shadow played a part in this cycle, the moon would not be visible because it would be in the total shadow of the earth. Also, the arc made by the shape of light would be different. Therefore, the shadow of the earth cannot be the cause of the phases of the moon.

We now need to look at the angle of the moon to the sun during the phases of the moon (Kavanagh, p.4). The first phase of the lunar cycle known as the new moon, is not visible to our eyes. After a few days, during phase two, we can see the crescent appear close to where the sun is setting in the western sky. With each phase of the moon, the angular distance between the sun and the moon grows wider. The moon appears higher

in our sky as the sun is setting until it reaches the full moon phase when it is at its greatest angular distance from the sun. The full moon will be rising in the east as the sun is setting in the west. As the moon enters the waning gibbous, the angular distance between The moon and the sun begins to shrink, the moon is seen rising in the sky just before Sunrise. The angular distance continues to shrink until the cycle begins again with the new moon.

It is the relationship of the sun, moon, and earth, which we now know causes the phases of the moon. It is the angular distance of the moon from the sun as well as its orbit around the earth that causes us to see the moon in different phases.

As for the origin of the moon, the most widely held hypothesis is that put forth by Dr. Hartmann and Dr. Davis in 1975. Their theory states that while the earth was forming about 4 billion years ago another planetary object about the size of Mars collided with earth causing a chunk of the earth to fly off and begin its orbit around the earth. This theory was supported by the fact that the moon has the same oxygen isotope composition as that of that moon and the density of the earth is very much like that of the moon. The moon's density is slightly lower than the earth's due to the lack of an iron core. The reason for the lack of iron on the moon is due to the collision occurring after the earth's core had hardened. Other theories for the moon's origin lacked the necessary evidence to support the hypothesis. These theories include the moon formed the same time as the earth and the moon was captured by the earth's gravitational pull as it traveled in space. The first theory fails because of the lack of iron on the moon and the second theory fails because the lunar rocks hold the same isotope of oxygen composition as the earths.

b. Benchmarks from AAAS

Looking at the benchmarks for science put forth by the AAAS, the following one reflects the focus of teaching the lesson on the phases of the moon and the origin of the moon:

4. **The Physical Setting**
   B. The Earth
   - Everything on or anywhere near the earth is pulled toward the earth's center by gravitational force.
   - The moon's orbit around the earth once in about 28 days changes the part of the moon that is lighted by the sun and the amount of the moon that can be seen from earth- the phases of the moon.

The above benchmark will be the basis for the lesson and the following benchmarks will support the teaching of the lesson as well as other scientific skills:

1. **The Nature of Science**
   A. Scientific World View
   - Scientific knowledge is subject to modification as new information challenges prevailing theories and as a new theory leads to looking at old observations in a new way.

3. **The Nature of Technology**
   A. Technology and Science

- Technology is essential to science for such purposes as access to outer space and other remote locations, sample collection and treatment, measurement, data collection and storage, computation and communication of information.

10. **Historical Perspectives**
    A. Displacing the Earth From the Center of the Universe
    - Motion of an object is always judged with respect to some other object or point and so the idea of absolute motion is misleading.

11. **Common Themes**
    B. Models
    - Models are often used to think about processes that happen too slowly, too quickly, or in too large or too small a scale to observe directly or are potentially dangerous.

    C. Constancy and Change
    - Physical and biological systems tend to change until they become stable and remain that way unless their surroundings change.
    - A system may stay the same because things are happening but exactly counterbalance one another.
    - Cycles can be described by their cycle length or frequency, what their highest and lowest values are, and when these values occur. Different cycles range from many thousands of years down to less than a billionth of a second.

12**. Habits of Mind**
    A. Communication
    - Locate information in reference books, back issues of newspapers and magazines, compact disk and computer database.

c. Most of the research on the misconceptions children have about the phases of the moon are done through interviews, models and questionnaires. There are many misconceptions held by both children and adults on how the phases of the moon occur.
In his book, *Heavenly Errors (2001),* Comins learned that many college students still held to the belief that the Earth's shadow causes the phases of the moon. He set about trying to explain that the phases are a result of the earth's orbit, the moon's orbit and the angular distance of the moon from the sun. This misconception seems to begin in the earlier years of childhood. In his study of children from ages 9-16, Baxter (1989) found five common notions concerning children and their beliefs about what makes the phases of the moon occur. These notions are as follows:

1. Clouds cover the part of the moon that we can't see
2. Planets cast shadows on the moon that we can't see
3. The shadow of the sun falls on the moon, so we can't see
4. The shadow of the Earth falls on the moon, so we can't see
5. Only the illuminated side of the moon can be seen from earth

Other researchers such as Rider (2002) and Schoon (1992) found that students held many misconceptions about the phases of the moon similar to those found by Baxter.

However, Rider (2002) and Schoon (1992) went a step further by suggesting ways to teach the topic concerning phases of the moon so that the children would unlearn the previous beliefs. Some of these suggestions included direct instruction, classroom activities and discussions, self-reflection and direct observations.
Looking at the research done for origins of the moon and children's ideas, I could not find one that I could use. Most of the studies that I was able to locate concerned the size of the moon and its relationship to the sun and the earth.

Part II

a. The sixth grade class that took the pre-assessment consisted of 32 students. Of the 32 students, 16 were boys and 16 were girls. The ethnic/racial grouping broke down as follows: 10 whites, 11 blacks, 4 Hispanics, and 7 Asians. The socio-economic level was generally middle class with 4 students being below the poverty level. Seventy percent of the class had been classified as mentally gifted. All of the students were motivated to learn and to perform to the maximum level of their ability. All of the students read at or above the seventh grade level. Ninety-five percent of the students scored above the 95th percentile in reading and math on the PSSA. One student had a severe speech impediment.

I introduced a picture of the phases of the moon on a transparency. I asked the student if they could identify what was going on in the picture. All of the students responded with the phases of the moon. We then discussed the possibility of how the phases occur. Most students thought that they had to do with the sun and the earth. I then proceeded to pass out a questionnaire with the exact picture of the phases of the moon (see appendix A). I asked the students if they could draw or describe how the phases of the moon occurred and how long it takes to go through all the phases. The students took about 35 minutes to complete the questionnaire. They were very hesitant about filling out the form. They did not want to be wrong and as much as I tried to tell them that it didn't count as a grade, they still hesitated to share what they knew. The students finally completed the questionnaires and turned them into me. It seemed that the students had a difficult time just telling me what they knew without grades being attached. I hope that students will change that perception in the year to come.

b. The sixth grade curriculum for Philadelphia schools calls for the teaching of astronomy to begin in January 2006. Included in this unit is the topic concerning moon phases. The standards put forth by the AAAS also calls for students to demonstrate an understanding of this concept by the end of eighth grade. Prior to the introduction of this topic, students will have demonstrated an understanding of the earth's rotation, revolution around the sun and gravity.

Two of the topics that will be covered are the phases of the moon and the origin of the moon. Knowing this, I looked at the research available concerning these two topics and came up with the following two questions: *What makes the phases of the moon occur?* and *What is the origin of the moon?* I choose these particular questions because they are at the heart of the lesson that I will be teaching.

After reading the Baxter (1989) study, I became curious about my own students' conceptions about moon phases. I also felt that this would be a great driving question for this topic. Knowing where the students' knowledge and beliefs lie will help me to set up effective lessons and activities that will hopefully direct them to correct their misconceptions.

The question for the origin of the moon was a multiple-choice question. I chose multiple-choice because I wanted to limit the number of responses to a realistic few. I felt that if I let the children respond freely, I would have difficulty categorizing their responses and thus have difficulty on getting a handle as to where to begin to teach the subject matter. The four responses also reflected the most common theories held by scientists.

c. Table 1. Responses of Students to the Question, *What makes the Phases of the Moon Occur?*

Responses Of Students	Caused by Earth's Shadow	Sun rotates Around moon	Sunlight	Time	Earth's Orbit	Moon's Orbit	Cloud Covered	Relationship Of Sun, Moon and Earth
Number of Students	3	2	3	1	6	9	3	5

When I began to sift through the responses, it seemed as if there were 32 different responses and I would have a hard time categorizing their answers. After a great deal of time and discussion with my group, I came up with the above table. Many of the students began the first sentence, "I think…" It was the first sentence that was the key to categorizing the responses. The first statement was the belief statement and the sentences that followed only tried to prove that what they believed actually does occur.
As you can see from the table, what followed the, "I think" was a multitude of answers that rather surprised me.

Some misconceptions that Baxter (1989) found in his study also appeared in the responses to my questionnaire. Like Baxter, I had 3 students respond that the moon phases are due to cloud cover, 3 responded that the Earth's shadow is the cause and 5 responded with the correct response, which is the relationship of the sun, moon and earth as the cause of the phases. The common theme, which appears to underlie the data, is that many students have an idea that the phases of the moon have something to do with orbit but they are unclear as to whose orbit. Some of the students believed that it is the orbit of the earth while others thought it was the orbit of the moon. Two of my students thought the sunlight caused the phases according to its position in the sky. One student thought that time was the culprit and that it just takes time to go through the phases. I was really amazed that 2 students thought that the sun orbits the moon. To me that is an extreme misconception for this age level.

Table 2. Theories for the Origin of the Moon

Choices	Moon Captured by Earth's gravity	Formed the Same Time as Earth	Earth was Spinning So Fast That a Piece Flew Off	An Object Collided with the Earth Causing a Large Chunk to be Sent into Earth's Orbit
Number of Students	14	6	1	11

Looking at the responses of the students, I would say that they are torn between the idea of the earth being captured and the idea of an object colliding with the earth sending a chunk into earth's orbit. Only 6 students believed that the moon formed at the same time as the earth and only 1 student believes that the fast spinning earth caused a piece of the moon to fly off into an orbit around the earth.

d. After analyzing the data, I see that my students need help in understanding how the phases of the moon occur. My students based their answers on their own personal observations and they interpreted these observations so that it made sense to them. They apparently have not had any exposure to understanding how the phases actually occur so they came up with their own explanations based upon previous experience, observation, or knowledge they had gained either from school or from their personal lives. In coming up with their own explanation, they believe that they have found a logical explanation for this occurrence.

However, what they perceive as the causes for the moon's phases did not exactly match the reality of how they occur. As shown in the findings, most students stated that the orbit of the earth or moon caused this occurrence. But they stopped short of going into a detailed explanation. If they understood how and why planets and satellites orbit, then they must have had an understanding of the concepts of gravity, rotation and revolution. As stated in the background, the moon orbits the earth but its orbit can vary above or below the earth's orbit around the sun. Therefore, the concept of plane may have to be introduced in order for the students to understand that the moon's orbit is not on the same plane as the earth's orbit all the time. This is the concept that needs to be clarified.

None of the students mentioned the angular distance of the moon from the sun as part of the reason for the phases. This concept must be introduced to all students in order for the students to change their perception of how the phases of the moon occur.
The students who mentioned time or the sun orbiting the moon are going to need a bit more help in some astronomical concepts such as a solar system and gravity based on the size of the planetary object. These concepts might best be handled in a possible review (KWL) of what students already know about our solar system.

These findings from my questionnaire have similar results to those found in the Baxter study (1989), Comins (2001) and Rider (2002). Not only do the young students hold misconceptions about the phases of the moon but also do adults. The greatest

misconception seems to be that the earth's shadow causes the phases of the moon. It is all the more necessary to have our students investigate their own perceptions for the moon's phases. By supplying them the tools and the encouragement needed to learn, we will be developing scientifically literate citizens who can think, investigate and decide on their own what is plausible and what is not plausible.

The question concerning the moon's origin reflects the present day students' ideas about our moon. Unfortunately, I was not able to find research done with students' ideas about the origin of the moon.

e. The implications of doing this questionnaire help the teacher to see the most common misconceptions students have concerning the moon's phases. It allows the teacher to see where their students are presently in relation to the concept being taught. This awareness is the starting point for the teacher. Once the teacher has this knowledge, he or she can then formulate a plan to take the students to where they need to be. It allows the teacher and the students to question, set up activities and investigations to help find the answers. The students become active participants in their own learning process and as a result will own that knowledge.

Keeping in mind where the students are in their thinking, I must teach the curriculum and the benchmarks assigned to sixth grade. It is my job to take them from where they are to where they need to be. The approach that I am going to take is that of a constructivism. This approach requires the student to be an active participant in the learning process. Students will need to participate in class discussions and will be able to reflect on their findings so as to incorporate new learning into their construct of the moon's phases.

Constructivism involves the interaction of the student with environment in order to construct meaning. It is very hard for the student to actually interact closely with the moon and its orbit, but there are other methods to be used. I would like the students to keep a moon journal. It would be necessary for them to observe the moon each evening (weather permitting) and record their observations in both pictures and words. Students who have a telescope with camera or video attached may use them to help record data. I would like the student to maintain the journal for 29 days or a full lunar cycle. For those days where the weather is inclement, students may use the newspaper or the Internet to obtain pictures or information. This journal would allow the students to actually travel through a lunar cycle and get a full visual as to what it looks like on various days. The journal would also allow the student to reflect on what they are seeing and learning so as to adjust their own construct to accommodate the new information.

Having the students learn about the angular distance of the sun and moon could also be included in the journal. The students would have to make note of what direction the moon is located each night and if it is high in the sky or rather low. By keeping track of direction and distance, students would be able to connect this concept to their own personal experience. In addition to this, I would like to introduce the students to the use of parallax by astronomers. Parallax helps scientists determine how far away an object is in the sky by measuring the distance in which the object appears to shift. Although the

students will not being doing any real calculations, they will hopefully be able to note any changes in appearance of objects in the sky, such as the moon or stars.

Concerning the orbit of the moon around the earth, I would like the students to play around with a model of the earth, moon and sun to try to replicate what they see in the night sky. I would like them to record what the model looks like which simulates what is occurring in the sky at night. Again, the journal will be used as a means for the student to reflect on the new information and make the necessary accommodations. This strategy may help the students to understand what is actually occurring in the night sky.

The idea of the moon's origin will take more the form of a research paper or rather an I-search paper. This type of paper has the student set up the question, which he/she would like to investigate. The students will be allowed to take the response they chose from the questionnaire and turn it into a question for investigation. This will allow the students to explore independently the idea of how the moon came to be. Once the students generate their driving question, they will be allowed to immerse themselves in their own learning of the subject matter. They will be obligated to turn in a paper of at least three pages in length, typed, double-spaced, 12 font and references in order to demonstrate what they have learned.

In conclusion, I feel that as a teacher, I need to be knowledgeable about the content in order to teach the content to the students. I also feel that it is necessary to find out what the students know and believe before beginning a lesson or a unit. This knowledge better informs me the teacher as to what direction I need to head and what activities would be appropriate for the students to engage. In the end, I would like my students to feel confident in the knowledge that they can answer the two questions, *What makes the phases of the moon occur?* and *What is the origin of the moon?*

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PRE-ASSESSMENT REPORT:

PHASES OF THE MOON AND ITS ORIGIN

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Appendix A

Phases of the moon taken from U.S. Naval Observatory Astronomical Applications Department located at http://aa.usno.navy.mil/faq/docs/moon_phases.html