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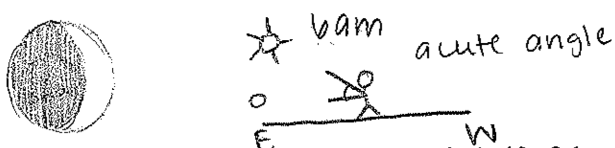
Introduction

The moon has been a topic of interest for many generations. From plotting and observing the moon to trips and explorations of the moon, humans as a group continue to want to learn more. Throughout this paper, we will dive further into our investigations of the moon by expanding on observations, predictions for rising and setting times, patterns in the observations, development of an explanatory model, and reflections on learning about the sun and the moon, the nature of scientific explanations, and inquiry approaches to learning and teaching. After studying the moon with these topics in mind, one can have a better understanding of why it has been so fascinating to humans since the beginning of time.

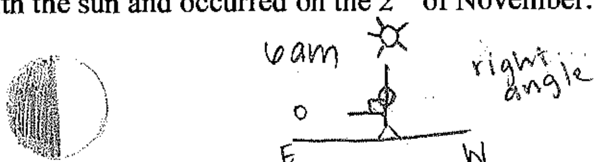
Observations

The new moon is a phase in which we cannot see the moon. The angle the sun and the moon create is at zero degrees. I experienced the new moon sometime between the 24th and 28th of October. As this is a time when one is unable to see the moon, it is sometimes hard to pinpoint the exact date. This means we must search for other clues, like experiencing a change in shape from waning crescent to waxing crescent when the moon is visible.

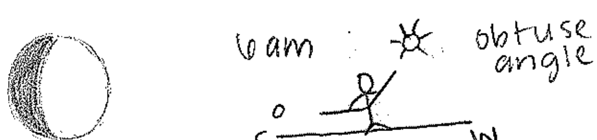
During the waxing crescent stage, the moon started to increase in visibility. The curvatures of the moon go in the same direction, while being open to the left. If we point one hand at the sun and the other at the moon, this phase creates an acute angle between 0 and 90 degrees with the sun and occurred between the 29th of October and the 1st of November.



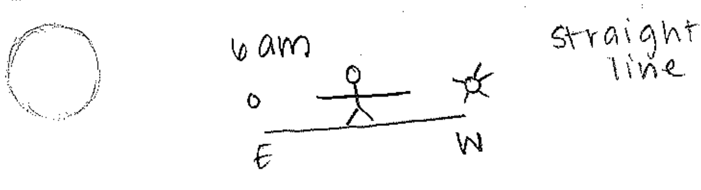
The first quarter moon is when exactly half of the moon can be seen. It is still increasing in visibility. Only the right side can be seen, making it look like a semicircle. If we point one had to the sun and the other at the moon, this phase creates a right or 90-degree angle with the sun and occurred on the 2nd of November.



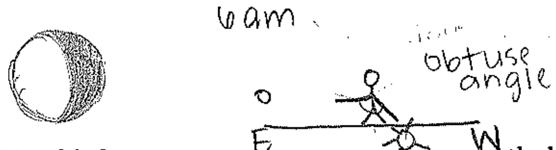
During the waxing gibbous stage, the moon continues to increase in visibility. The curvatures of the moon go in opposite directions, with the right side being fully visible and the left side continuing to become more visible. If we point one hand at the moon and the other at the sun, this phase creates an obtuse angle between 90 and 180 degrees with the sun and occurred between the 7th and 10th of October.



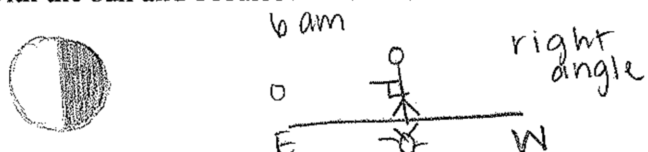
The full moon is the time when the moon is at its fullest. It occurs at a time when it has the most direct sunlight, and therefore appears as a full circle. If we point one hand to the moon and the other at the sun, a straight line or 180-degree angle is formed between the sun and the moon. The full moon occurred on the 11th of October.



During the waning gibbous stage, the moon starts to get smaller. The curvatures of the moon go in opposite directions, with the left side being fully visible and the right side beginning to reduce in visibility. If we point one hand at the moon and the other at the sun, this phase creates obtuse angles, or angles between 180 and 90 degrees with the sun and occurred between the 12th and 18th of October.



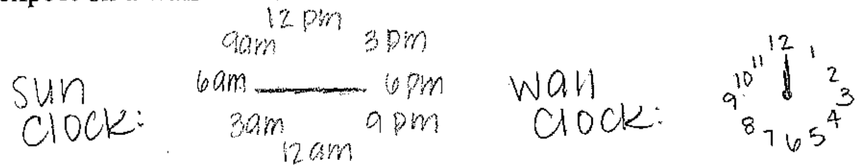
The third quarter moon occurs when exactly half of the moon can be seen. It is still reducing in visibility. Only the left side can be seen, making it look like a semicircle. If we point one hand at the sun and the other at the moon, this phase creates a right or 90-degree angle with the sun and occurred on the 19th of October.



During the waning crescent stage, the moon continues to decrease in visibility. The curvatures of the moon go in the same direction, while being open to the right. If we point one hand at the moon and the other at the sun, this phase creates angles acute angles, or angles between 90 and 0 degrees with the sun and occurred between the 20th and 24th of October.

Predictions of When and Where to Look for the Moon

At times, both the moon and the sun are visible during the same time. We can then point a hand at both to determine the angle the two create. This angle allows us to predict the rising, setting and high in the sky times of the moon based on the position of the sun and the current phase of the moon. When considering this angle, it is important to remember that the timeline, or clock, for the sun-moon relationship is divided into 24 hours. This clock begins with the sunrise at 6 AM with the sunset occurring at 6 PM. Therefore, when the angle formed by your arms is horizontal (180°), you are pointing to 6 and 6 as opposed to the 3 and 9 you would expect on a wall clock.



To predict the rising, setting, and high in the sky times for the moon, we must first know the angles that the we create by pointing one arm at the sun and the other at the moon for each different phase.

Between the new moon and the first quarter, our arms pointing at the moon and the sun create an acute angle on the sun clock, so we know that when the sun rises at 6 AM, the waxing crescent moon will rise around 9 AM.

During the first quarter, our arms pointing at the sun and the moon create a right angle on the sun clock, so if the sun rises at 6 AM we know that the moon rises at 12 PM.

Between the first quarter and the full moon, the moon and the sun create an obtuse angle on the sun clock, so if the sun rises at 6 AM the waxing gibbous moon will rise around 3 PM.

During the full moon, our arms pointing at the sun and the moon create an angle of 180°, or a straight line on the sun clock. This means that if the sun rises at 6 AM, the full moon will rise at 6 PM.

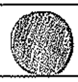
Between the full moon and the third quarter, our arms pointing at the sun and the moon will again create an obtuse angle on the sun clock, but this time it will be open to the bottom half of the sun clock. If the sun rises at 6 AM, the waning gibbous moon will consequently rise around 9 PM.

During the third quarter, our arms pointing at the moon and the sun will create another 90° angle, but will again be open to the lower half of the sun clock. The sun will rise at 6 AM and the third quarter moon will rise at 12 AM.

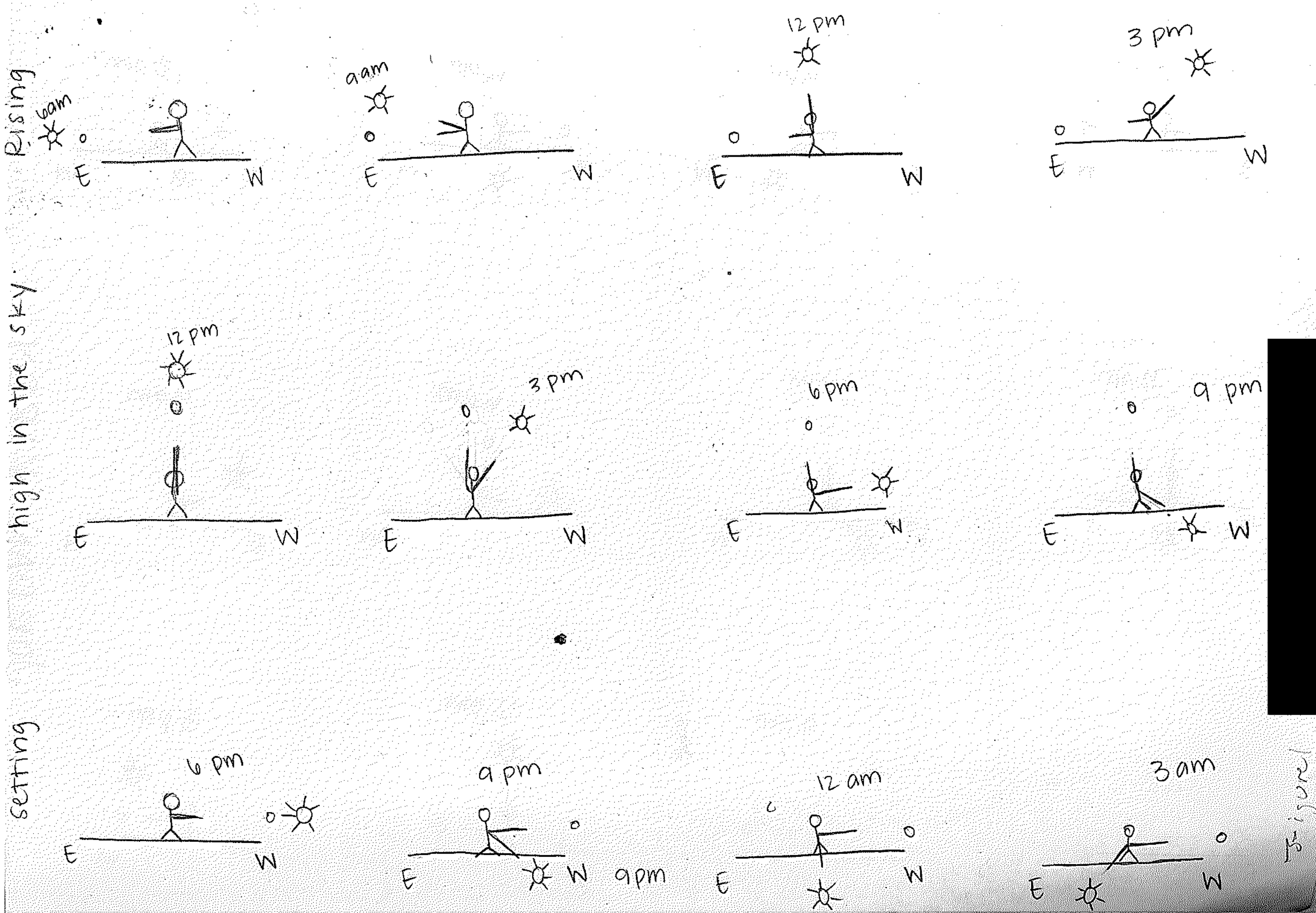
Lastly, between the third quarter and an entirely new moon, the angle formed by pointing at the moon and the sun will again be acute, but open to the bottom portion of the sun clock. When the sun rises at 6 AM, the waning crescent moon will rise around 3 AM.

The moon, like the sun, rises and sets in about 12 hours, and is high in the sky at approximately the midpoint of these 12 hours. This is why when you know the angles formed on a sun clock, you can predict the rising, setting, and high in the sky times of every phase.

This chart can be used as a guide when looking for the moon. It helps predict when the moon will be most visible to you. Although we often think that the moon should always be most visible at night, it is not always the case. The contrast of the night sky helps when searching for the moon, but the best way to determine visibility is to know when each particular phase will be at its highest.

Name of Phase	Shape	Angle Formed by Sun and Moon	Predicted Rising Time	Good Time to Look	Predicted Setting Time
New Moon		0°	6 AM	12 PM	6 PM
Waxing Crescent		0-90°	6AM-12PM ≅ 9 AM	12PM-6PM ≅ 3 PM	6PM-12AM ≅ 9 PM
1st Quarter		90°	12 PM	6 PM	12 AM
Waxing Gibbous		90-180°	12PM-6PM ≅ 3 PM	6PM-12AM ≅ 9 PM	12AM-6AM ≅ 3 AM
Full Moon		180°	6PM	12 AM	6 AM
Waning Gibbous		180-90°	6PM-12AM ≅ 9 PM	12AM-6AM ≅ 3 AM	6AM-12PM ≅ 9 AM
3rd Quarter		90°	12 AM	6 AM	12 PM
Waning Crescent		90-0°	12AM-6AM ≅ 3 AM	6AM-12PM ≅ 9 AM	12PM-6PM ≅ 3 PM

new moon (0° ∠) | waxing crescent (acute ∠) | first quarter (right ∠) | waxing gibbous (obtuse ∠)



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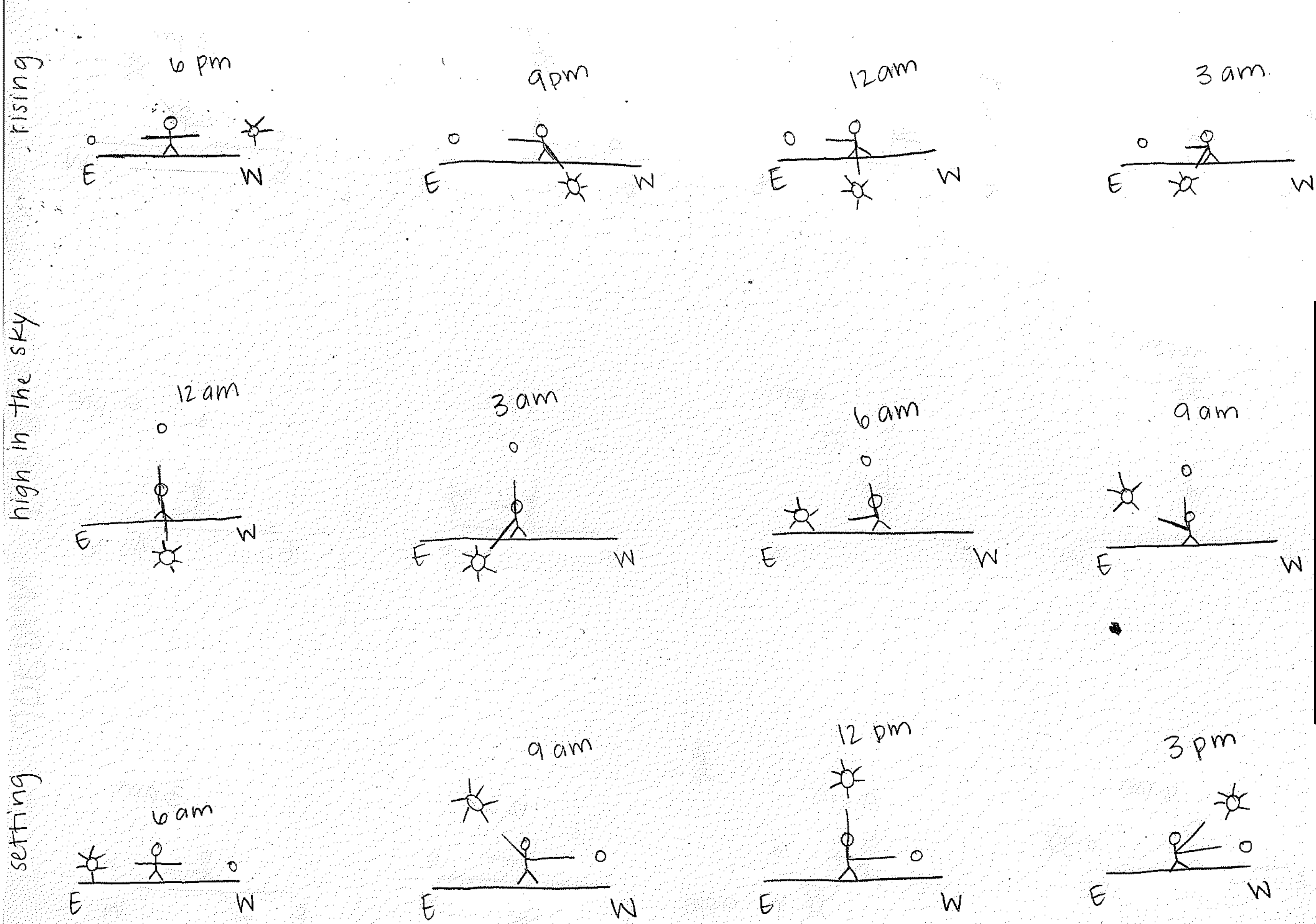
full moon straight line/180° ∠	waning gibbous (obtuse ∠)	third quarter (right angle)	waning crescent (acute ∠)



Development of an Explanatory Model for the Phases of the Moon

There are many questions we have about the moon, as well as many ways to answer these questions. Some questions can be answered by observing the moon and its patterns while keeping in mind the relevant powerful ideas about light and shadows. Other questions need to be answered with explanatory models or inferences. Through a combination of these methods, one should be able to gain a better understanding of the moon and its interactions with Earth and the sun.

Questions about the moon. There is an infinite amount of questions that one could ask concerning the moon. Some of the most prevalent questions are: "What is the relationship between the apparent shape of the moon and the angle formed by pointing one arm at the moon and one arm at the sun?" "How does the moon appear to move during a 24-hour period?" "On which side of the moon will the sun be for each phase? Who appears to be chasing whom across the sky?" and "How does the moon appear to move over several 24-hour periods?" If we consider these questions individually, we can see how they can each be answered by observing the moon over several 24-hour periods.

When considering the relationship between the apparent shape of the moon and the angle formed by pointing one arm at the moon and the other arm at the sun, we must first be presented with a day that both the sun and the moon are visible at the same time. While observing, we take one arm and point it at the sun while the other arm is pointed at the moon, and then measure the angle formed by our arms. Also, record the shape of the illuminated portion of the moon. If this is done multiple times, a person will observe that as the illuminated portion of the moon grows, the corresponding angle created by pointing at the sun and the moon will also grow.

If you were to observe the moon multiple times during a 24-hour period, you would notice that it does not remain in the same location. Much like the sun, the moon appears to rise in the east and sets in the west. Based on the phase of the moon, its location can be found using the angular relationship with the sun during that phase.

To determine whether the sun is chasing the moon or the moon is chasing the sun, one must observe the moon several times during a 24-hour period in which the sun and the moon are visible. We must do this over several 24-hour periods to answer this question relative to the phases of the moon. If you watch the moon over a full lunar cycle, you will observe that from the new moon through the waxing crescent, first quarter, and waxing gibbous phases, the moon appears to be chasing the sun, as the moon is located to the left of the sun. From the full moon through the waning gibbous, third quarter, and waning crescent phases, the sun appears to be chasing the moon, as the moon is located to the right of the sun.

If you observe the moon over several 24-hour periods at the same time, you will notice that it will not be in the same location each night. An easy way of determining the location of the moon is using other things such as stars or trees as a comparison. Observing from the same location is key for using these comparisons. From night to night, the moon appears to be moving from west to east. This observation is again supported by the angles created between the sun and the moon during each phase.

Some questions cannot be answered simply by observing the moon. Questions such as "Why does the moon appear to move in these ways?" and "Why does the moon seem to have different shapes at different times?" are questions that must instead be answered using an explanatory model of the Earth, moon, and sun relationship.

Using powerful ideas about light and shadows. From a source, light travels in all directions and in a straight line. Light also reflects off of objects in straight lines and in all directions. In order to see something, light must reach your eyes. In this case, light travels from the sun in straight lines and all directions, reflects off of the moon in straight lines and all directions, and then eventually reaches your eyes. This explains why we are able to see the moon from Earth.

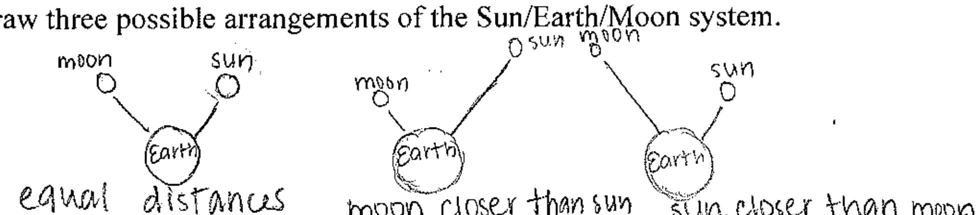
Explaining day and night. There are two explanatory models for day and night. The first explanatory model is the idea that the sun moves around the earth in a 24-hour period. This would explain why it is light during part of that day and dark during the other part of the day, because during the dark part of the day, the earth would create a shadow on its side opposite the sun. If the sun revolved around the earth, it would explain why we experience day and night as well as why the sun rises each day. This model is represented by the sun clock used previously to predict where and when to look for the moon.

The other explanatory model would be that the earth rotates on its axis in a 24-hour period. This would also explain the shadow cast by the earth itself on the portion of the earth experiencing night, along with why the sun rises each day. If the earth does in fact rotate on its axis, it would also explain why the moon rises and sets each day.

Modeling the Sun/Earth/Moon system. To answer some important "why" questions about the moon, it is easiest to create a model of the sun/Earth/moon system. This can be done outside using the sun or inside using a lamp, along with a ball or your fist. The sun and the lamp represent the sun, the ball or fist represents the moon, and your eyes represent your eyes here on Earth. If you allow the ball or fist to revolve around you, the lit portions change shape in the same way that the moon's lit shapes change. By creating this model, we can infer that the moon revolves around the Earth, causing the moon's changing shapes as we see the moon from here on earth.

Inferring the arrangement of the Sun/Earth/Moon System.

Draw three possible arrangements of the Sun/Earth/Moon system.



Because we have already inferred that the moon revolves around the earth, we can therefore infer that it is closer in proximity than the sun to the earth. This means that the moon is much closer to earth than it is to the sun.

Further evidence of this is found in the angles created by pointing one arm at the sun and the other at the moon. On October 20th at 9:45 A.M, we were fortunate enough to be able to go up to the roof and observe the sun and the moon. We found that the sun and the moon created a 90-degree angle, something that would be possible if the moon is revolving around the earth. We used a ball representing the moon, a lamp representing the sun, and our eyes representing our eyes here on earth to test the possible arrangements of the sun/earth/moon system. While standing in one spot, we placed the ball and the lamp equal distances away from us while still maintaining the 90-degree angle that is characteristic of pointing at a first or third quarter moon and the sun. Much more than half of the ball was lit, causing us to infer that the moon and the sun are not equal distances from the earth.

We did this same experiment with the ball at a further distance away from us that the lamp, while maintaining a 90-degree angle if we were to point one hand at the lamp and one hand at the ball. Much less than half of the ball was lit, causing us to infer that the moon is not further away from earth than the sun.

Lastly, we performed the same experiment with the ball closer to us than the lamp. We kept the 90-degree angle caused by pointing one hand at the lamp and the other at the ball just like we would for a quarter moon and found that about half of the ball was lit. During both first and third quarter moons, exactly half of the moon is lit; causing us to infer that the moon is closer in proximity to the earth than the sun.

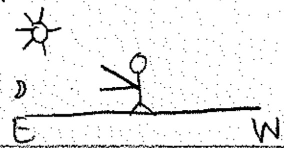
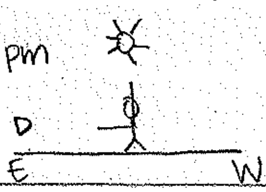
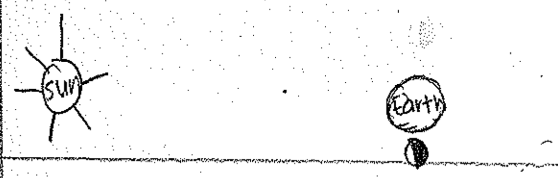
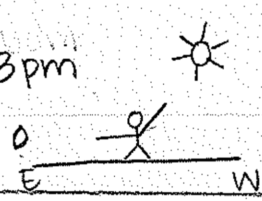
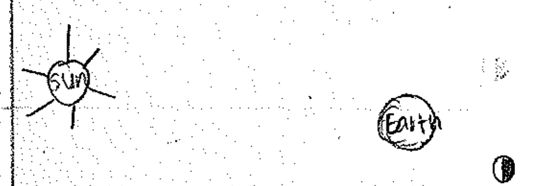
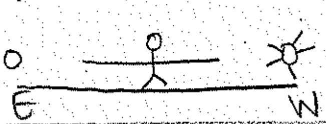
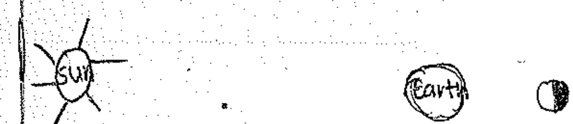
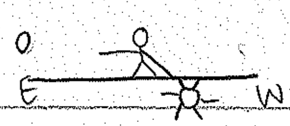
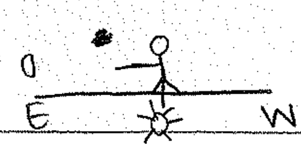
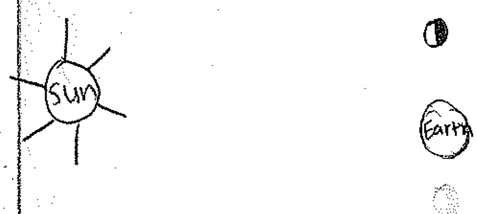
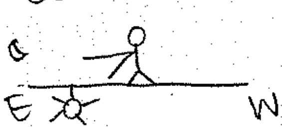
We also used a pinhole camera to determine the diameter of the sun. Given that the image of the sun was proportionate to the sun itself, we were able to set up an equation (after being told the distance of the sun from the earth). If used with a full moon, the image of the moon projected would have been about the same size as the sun, but the distance from the moon to the earth would have been much smaller. After comparing the two proportion equations, we can see that though the sun and the moon appear to be similar in size, their relative distances from the earth are what cause this.

Sketch two perspectives for each phase:

refer to figs 1 and 2

What do you see here on earth? For each phase, draw a stick figure showing one arm pointing to the Sun and one arm pointing to the moon:

What would you see if you were to look down upon the Sun, Earth, and Moon from way above the solar system? For each phase, draw the arrangement we have inferred for the Sun, Earth, and Moon with their relative sizes and distances from one another. Represent the shape of the moon as it would appear to someone looking down on the Sun/Earth/ Moon system from above.

Our Perspective		Above the solar system
New moon: 6am		
Waxing Crescent: 9am		
First Quarter: 12 pm		
Waxing Gibbous: 3pm		
Full moon: 6 pm		
Waning Gibbous: 9 pm		
Third Quarter 12 am		
Waning Crescent: 3am		

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Considering the role of the Earth. We see that the moon rises in the east and sets in the west during a 24-hour period: we can explain this by Earth rotating on its axis. We see that over several 24-hour periods the moon appears to move across the sky from west to east. We can explain this by the moon revolving around the earth. This is caused by the earth's gravitational force on the moon, which maintains the orbit of the moon around the earth.

Using the explanatory model to answer other questions about the moon. There are many more questions about the moon that can be answered using the explanatory model of the sun/earth/moon system. These questions include but are not limited to: "Why is it that sometimes we can not see the Moon even if the sky is clear all day and all night?" "What is an eclipse of the moon and what is its cause?" and "What is an eclipse of the sun and what is its cause?"

To explain why it is that sometimes we cannot see the moon even if the sky is clear all day and night has to do with the revolution of the moon around the earth. From our perspectives on earth, we can only see the portions of the moon that are illuminated. If the shadow cast by the moon on itself is on the portion nearest to earth, it will not matter how clear the skies are, we still will not be able to see it. This occurs when the moon is in between the sun and the earth, as the sun illuminates the portion of the moon facing away from the earth.

An eclipse of the moon is when the moon travels directly through the earth's shadow. The earth shields the moon from the light of the sun. On earth, we are unable to see the fully lit moon for a short time, sometimes an hour or more.

An eclipse of the sun is when the moon travels directly between the sun and the earth, causing a shadow of the moon to fall on earth. From our perspective on earth, we are unable to see the sun for a short time. Solar eclipses are caused by shadows cast by the earth on the moon.

Reflections on Science Learning and Teaching

The key to promoting the comprehension of the interactions between the earth, the sun, and the moon is presenting this material in an effective and meaningful way. This involves capturing students' attention, keeping their attention, and documenting growth in understanding. Although many forms of teaching exist concerning science, the inquiry approach to science learning is one of the most effective.

Critiquing media by exploring moon websites with friends and family. The diagram on this website helped my friend understand the cause of the moon phases. There was also an explanation that went along with the diagram that helped to further his understanding. Although the diagram and explanations made sense to both of us, my friend wasn't able to fully grasp the powerful ideas of light and how they affected both the moon cycle and our perspective here on earth. I learned that it is much better to teach someone something through experiments and hands-on activities. My friend understands the moon cycle, but not nearly as well as someone that had been taught through inquiry methods to science learning. Had he been able to do the experiment including the ball and the lamp, he would have understood the concept more fully.
http://www.moonconnection.com/moon_phases.phtml

Documenting changes in understandings about the sun, earth, and moon. As a whole, my understanding has changed a lot. When asked in September why the moon seemed to have different shapes at different times, I said, "The earth shadows the moon from the sun." I was thinking that the earth must shadow the moon from the sun, much like an eclipse. I knew that the visibility of the moon had something to do with shadows, I just didn't know exactly what. When asked the same question in November, I responded with, "The moon appears to have different shapes because it is revolving around the earth, receiving sunlight in only certain portions. (Light travels in straight lines, the illuminated portion is from our perspective)." I believe now that the illuminated portion of the moon has to do with our perspective here on earth. Because the moon is revolving around the earth, it is true that only certain portions receive light due to the moon's location around the earth. Not only has my understanding of the moon cycle increased, but I am now able to apply other scientific ideas to defend my ideas.

Documenting changes in understandings about the nature of scientific explanations. From September to November, my understanding of the nature of scientific explanation has remained largely the same. In September, I wrote that, "A scientific explanation is on that includes observations from an experiment." I understood that a scientific explanation was one that needed to be supported by observations. When asked again in November, I said that, "A scientific explanation is on that can be supported by experiments and evidence." I again realized that scientific explanations need to be supported by observations in the form of experimenting, but I added that evidence from these experiments was also needed. Though I came out with very similar ideas about scientific explanations as when I went in, I feel as though I have a better idea of how to ask better questions that lead into performing said experiments.

Documenting changes in understandings about inquiry approaches to learning and teaching. From September to November, my understanding of inquiry approaches to learning and teaching has remained largely the same. In September, I wrote that, "Inquiry approaches are ones in which students ask questions and teachers shape lessons to fit students' interests in order to make lessons meaningful." I knew that inquiry approaches were mostly student-led, and that the students' questions helped shape the lessons. In November, I wrote that, "An inquiry approach is one that allows natural curiosity to shape a lesson." This is just a shorter version of what I said in September, in that I still understood that natural curiosity from the students is supposed to lead lessons. Though I came out with very similar ideas about inquiry approaches to learning and teaching as when I went in, I feel as though I have a better idea of how to facilitate lessons and experiments for my future students.

Engaging students in learning about science while watching the moon. Students are naturally curious, so a simple task like asking them to observe the moon will surely capture their attention. Getting parents and family involved can also be beneficial, as young students really look up to their families. By allowing them to record their observations, teachers can facilitate meaningful discussions about the moon. In doing these things, student learn to observe, record, and discuss their findings with peers. All of these skills are very important in every aspect of science!

Reflecting on what you learned about science learning and teaching from this course project. I have learned that when lessons build off of each other, they become much more meaningful. When our explorations of light tied into our explorations with the moon, I became all the more interested. Lessons that make connections to things that students already know will help to create a more significant lesson. In turn, the students will learn and retain more than if connections had not been made.

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This paper is a pleasure to read. Congratulations!
Emily