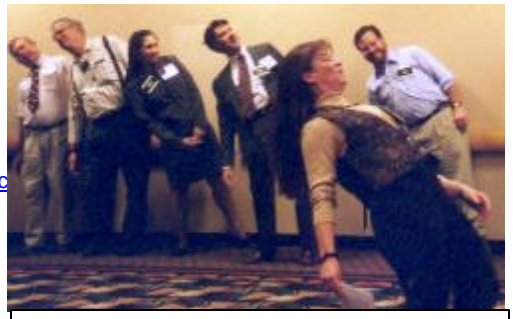
Kinesthetic Astronomy



Cheri Morrow leads a group of teachers and astronomers in the Sky Time lesson at a workshop held at the Atlanta 2000 meeting of the American Astronomical Society

Adapted from Space Science Institute's "Lesson 1: Sky Time"
http://www.spacescience.org/Education/ResourcesForEducators/CurriculumMaterials/Kin_Astro/

Audience: 5th grade up (must know something about the rotation and revolution of Earth and how these are related to day, year, seasons)

Pre-Activity questions/discussion (optional)

1. How do you think humanity kept track of time before the invention of clocks and watches?
2. How does the Sun appear to move in the sky?
3. Why does the Sun appear to rise in the East and set in the West?
4. Do we see the same stars at different times of night? Why/Why not? What about different time of the year?
5. What time of year do we experience more daylight hours?
6. At what time of year is the Sun highest in the sky at noon?
7. Why is it hotter in summer and colder in winter?
8. Will people in Europe see the same stars tonight as people in the US? What about people in Australia?

Setup: Girls need to form circle with arms outstretched to their sides, not touching others. Choose something for the sun (could be the leader or a ball) and put this in the middle of the circle.

- Tell them to imagine they are each representing Earth
  - Top of their head – North Pole
  - Waist – equator
  - Above waist – Northern Hemisphere
  - Below waist – Southern Hemisphere
  - Line from head-to-toe – the rotation axis of Earth

Props: Flashlight helpful

Stop whenever you sense the girls have had enough.

I. The astronomical Meaning of a Day

1. "Face directly toward the symbolic sun with your arms outstretched. What time is it at your nose?"
   a. (Noon, because the Sun is midway between their outstretched arms)
2. "Face directly away from sun with your arms outstretched. What time is it at your nose?"
   a. (Midnight)
3. "What time is it at the back of your head?"
   a. (Noon)
4. "Remember, your head is the North Pole. Imagine you have a standard globe wrapped around your belly so that the US is on the part of the globe facing forward. If your

nose represents Sky High Ranch, where on Earth would the back of your head represent?"

a. (Approximately eastern Afghanistan)

5. "Turn around so that it is noon at Sky High. Think and discuss with each other which of your hands represents Eastward (towards NY on the US map) and which hand represents Westward (towards California). Raise the thumb of the "eastward" hand. Tuck your 'westward' thumb inside your fist. This represents the Statue of Liberty in NY harbor."
    a. (Should raise thumb of their left hand).
        - (For those who have trouble visualizing, the last page has a map of the US. Put this on their belly.)
6. "Remember, it's noon on your nose. Your outstretched left hand represents Eastward. What is visible in the sky at any given time is out in front of your arms; what is behind your arms is not visible at that time. A person located on your nose, looking out in a direction parallel to either of your arms will see whatever is low on the eastern or western horizon. Which way does the Earth rotate? Rotate yourself as the Earth would rotate."
    a. (They should rotate towards the East/left.)
        - If needed, ask: Where does the Sun set. (West). Give girls time to discover how to make the Sun "set" in their west (ie disappear from view behind their outstretched west (right hand) and "rise" in their East. Encourage them to hold up the thumb of their Eastward hand to remind themselves which direction is which.
        - Ask them to continue rotating around and confirm that the Sun is rising in their East (ie appearing in front of their outstretched "east" (left) hand as they continue to turn) and setting their West.
7. "Which way does Earth rotate, 'toward the East' or 'toward the West'?"
    a. (Toward the East)
8. "Return to 'noon-at-noses' position. Rotate to 'sunset'. What time is it at your nose?"
    a. (They should have right arm towards sun. Approx 6 pm.)
9. "Rotate to midnight at your nose. Now rotate to sunrise. About what time is it at your nose?"
    a. (They should now have left arm towards sun. Approx. 6 am)
    - *For older girls, try to get them to 'sense' the Earth's rotation. Try to reverse the usual perception of the Sun moving and instead try to perceive the Earth turning toward the East.*
    - *Take older girls through a 45° rotation, starting from noon-at-noses position. Give them time to work out what time of day it is at their noses (mid-afternoon) and where the sun is in their 'sky' (western).*
10. "Rotate to where you see stars other than the Sun." "Why are you able to see these other stars?"
    a. (They should rotate towards having their back towards the Sun. They can see these other stars because the sun is not above the horizon; it is dark.)
11. "Pick out some object you can see and give that object the name of a constellation (e.g., the Big Dipper). Rotate through a day and estimate the times when your 'constellation' is visible to the person on your nose."
12. "How long does it take for Earth to rotate around one time?"
    a. (24 hours = 1 day)
13. "What have we been ignoring about Earth's rotation?"

    a. (The tilt of Earth's axis – relative to Earth's orbital plane about the sun.)
14. "We tilt 23.5° from the vertical with the North Pole (the top of our heads) pointing towards which star?"
    a. (Polaris or the North Star)
15. "Return to Noon. Tilt from the waist about 23.5°, or about midway between vertical and 45° with your North Pole pointing towards [SELECT SOME OBJECT OUTSIDE YOUR CIRCLE THAT CAN REPRESENT POLARIS.] Try to rotate your body around your tilted axis (i.e., keep your heads pointed towards our Polaris).
    a. (Note that depending upon their position in the circle, each girl will be bent a different way, some forwards, some backwards, others sideways, etc. As they rotate, this will be physically challenging! Give plenty of time to work this out.)

II. The Astronomical Meaning of a Year

1. "Return to 'noon-at-noses' and ignore your tilt for now (stand vertically). Whose birthday is closest to today? How many trips around the Sun have you made in your life?"
    a. (Pause to allow time for everyone to reflect on this question making the connection between their age in years and the fact that it takes one year for Earth to make one trip around the Sun.)
2. "What is the difference between 'orbit' and 'rotation'?
    a. (Rotation: spin of a body around an axis. Orbit: Movement of a body around an object.)
3. "How many times does Earth *rotate* around its axis during one *orbit* around the Sun?"
    a. (365)
4. "How much does the Earth move in its orbit of the Sun in one day?"
    a. $1/365^{th}$ of the way around.
        - Older girls can be asked "About how many degrees would this be?" Since there are 360°
5. "Face our North Star (Polaris). Tilt our 23.5°. What time of day is it for you?"
    a. (Everyone should be doing a forward bend, but their time of day will vary. You might want to ask them individually. Those on the 'North' side of the circle will be in nighttime hours, those on 'South' will be in daylight hours, "East' near sunrise, 'West' near sunset.)
        - (Sometimes girls will struggle to sense the difference between tilting their head over by bending at the neck vs bending at the waist. You may need to gently coax their head square over their shoulders and then coax them to bend in the appropriate direction.)
6. "Look around and notice how the time of day is different for everyone."
7. "Now make an Earth year happen (ie, one orbit around the Sun). Do not worry about the daily rotation, just focus on keeping your tilt – your forward bend."
    a. When they question which way to orbit – tell them "Earth's orbit is counterclockwise around the Sun."
        - (Some will want to rotate. Remind them to continue bending forward. You want them to remember that the axis maintains a fixed orientation in space.)

8. "Now let's slowly rotate while we slowly orbit. Concentrate on maintaining your tilt towards our North Star (Polaris). "
    a. This will be very challenging. Make sure they don't get too dizzy! Stop if it is too difficult or when appropriate.

III. The Astronomical Meaning of Seasons (younger girls many not be able to understand this)

1. "Return to noon-at-noses. Tilt towards our North Star (Polaris). Who has her upper body (Northern Hemisphere) tilted most directly toward the Sun? What time of year is it when Earth is in these positions in its orbit about the Sun?"
    a. (The summer solstice (approx June 21) is when the Earth's North Pole is tilted most directly toward the Sun.)
2. "Who is tilted the most away from our Sun? What time of year is it for you?"
    a. (The first day of winter (winter solstice) – approx. Dec 21)
3. "Ignore Polaris. Everyone tilt so your "North Pole" (top of your head) is away from the Sun. What season is your Northern Hemisphere in?"
    a. (Winter. Everyone should be doing back bends away from the sun.)
4. "Is the Sun high or low in your sky?"
    a. (Low. They should sense that they have to cast their eyes downward to see the symbolic sun in the center of the circle.)
5. "Now tilt toward the Sun as if in summer. Do you have to look higher or lower in the sky to see the Sun?"
    a. (Higher. They should all be doing forward bends toward the sun and furrowing their foreheads to look upward to see the sun.)
6. "Does the Sun take a longer or shorter path across the sky in the Summer than it does in the Winter?"
    a. (The arc is higher in the Summer, meaning that the Sun spends longer in our visible sky, rising earlier and setting later.)
7. "What is the difference between the way that the rays of the Sun are hitting the person on your nose in Summer than in Winter?"
    a. (The rays beat down more directly in Summer than in Winter.)
8. "What difference does this make to the intensity of the heat?"
    a. (Rays hitting at an angle will be less intense, thus cooler.) [This can be demonstrated with a flashlight. Shine it directly down onto the floor. Then direct the flashlight at an angle and compare the dispersion of light. Less rays hitting a square inch would be less intense.]
9. "When you're trying to warm your hands over a campfire, how do you hold them?"
    a. (You hold them at an angle perpendicular to the heat source vs holding them with their fingertips pointed toward the source. Your palm feels hotter when the heat strikes the surface directly instead of in a glancing way.)
        - A common misconception is that seasons are caused by changes in Earth's distance from the Sun. In fact, Earth's orbit is almost perfectly circular, being very slightly closer to the Sun during winter in the northern hemisphere. It is warmer in the Summer because the rays hit more directly and the Sun spends more time shining in our visible sky.
10. [Find the girls whose birthdays are closest to the summer and winter solstice (June and Dec 21) and have them move to the appropriate orbital positions.]
    a. (Winter Solstice closest to Polaris; Summer across circle)

11. [Find the girls whose birthdays are closest to the equinoxes (Spring – March 21; Fall – September 21) and have them move to the appropriate orbital positions.]
    a. (This may be a little trickier. They may need to be reminded of the counterclockwise motion of Earth around the Sun. Allow the group to discuss. You can check by looking at the "Flagpole Diagram" on the last page.)
12. "Everyone, go stand in the approximate position of the Earth's orbit around the sun on your birthday." [Once they have found a place,] "Let's go around the circle and see if we have it right."
13. "Face noon-at-noses. Assume the appropriate tilt. Rotate while maintaining your tilt."
    a. [Hum, "Happy Birthday"] as they rotate.

IV. The View of the Night Sky

1. "Ignore the tilt and stand straight. Face midnight-at-noses. Identify a major object that you can see in front of you. Imagine this to be a constellation and invent a name for it. (for example, crooked pine tree constellation)"
    b. [Go around the group and have them share their names. Remember which one is the furthest away.]
2. "Why do people on the night side of Earth see different stars in their night sky at different times of the year?"
    a. (Because at different times of the year, the night side (the side facing away from the Sun) of Earth faces out in different directions in space.)
3. "Rotate. How does your constellation move across the sky?"
    a. (Stars 'rise' and 'set' like the Sun and thus appear in different parts of the sky as the night progresses. If they get into the discussion about the motion of stars around Polaris, you can refer to the FAQ page.)
4. [Select the "constellation" furthest from the group.] "Everyone, look at the _____ constellation. Now rotate and estimate the times of night when it would be visible at your nose and where it would be in your 'sky'. [Go around the group and have them report out.]
    a. (Refer to "flagpole diagram". The closer they are to the closest position to the constellation, the more time they will be able to see it. Some students will not be able to see it because the Sun is up.)

V. Questions for Reflection

(These are some of the questions asked at the beginning. Now have them demonstrate their answers with their bodies or by selecting the girl in the correct orbital position.)

1. Why does the Sun appear to rise in the East and set in the West?
2. Do we see the same stars at different times of night? Why/Why not? What about different time of the year?
3. Who is at the orbital position representing the time of year that we experience more daylight hours?
4. Why is it hotter in summer and colder in winter?
5. Will people in Europe see the same stars tonight as people in the US? What about people in Australia?

FREQUENTLY ASKED QUESTIONS (FAQ)
For the Sky Time Lesson

FAQ 1: The patterns of the stars (constellations) appear to rise and set because of Earth's rotation, but do the stars themselves move?
Answer: Yes, the stars themselves do move, but because they are so far away their motion is imperceptible to us with the naked eye, and thus the patterns of stars (the constellations) will appear unchanged for many lifetimes.

FAQ 2: Why is it that some constellations (such as the Big Dipper at northern and mid-latitudes) do not appear to rise or set, but can be seen all night and all year round?
Answer: Because Earth rotates around an axis pointed toward Polaris, the objects in the sky will all appear to move around this star. If you were at the North Pole, where Polaris appears directly overhead in the sky, no stars would rise or set, but the dome of the sky would appear to rotate around parallel to the horizon. At lower latitudes, those stars appearing closest to Polaris in the sky still would not rise or set, but instead would appear to move in circles around Polaris. Those stars appearing farther away from Polaris (e.g. farther south in the sky) will still be moving in circles around Polaris, but these circles intersect the horizons and thus the stars appear to rise and set. So, if you are at 40°N latitude, then Polaris appears 40° above the northern horizon, and stars that appear within 40° of Polaris (such as those in the Big Dipper) will appear to move around Polaris without rising or setting. These are called *circumpolar* stars. Your latitude dictates which stars will be circumpolar and which stars will appear to rise and set.

FAQ 3: Do people at different latitudes [say, the North Pole, the equator, and the South Pole] see the same collection of stars when they look up at night?
Answer: No, because we are on a spherical earth, and thus when we are at different latitudes we are looking out in different directions in space when we look directly up overhead. Using a globe (or other spherical object) and a small doll or action figure, you can show how the direction of "directly overhead" changes as the doll is positioned at different latitudes from pole to pole.

FAQ 4: If the sun is a star, why is it so much brighter than the other stars?
Answer: Other stars are much farther away than our sun. The sun is about 100 million (100,000,000) miles away, but even the nearest star is about 24 *trillion* 24,000,000,000,000) miles away. The light we receive from a particular star depends on how far away it is.

FAQ 5: Where do I find Polaris in the sky?
Answer: At the North Pole, Polaris appears directly overhead in the sky. At lower latitudes Polaris appears closer to the northern horizon. Polaris is located above the northern horizon by the same number of degrees as the north latitude at your location. In other words, if you are at 40°N latitude, then Polaris appears 40° above the northern horizon. If you are at the equator, then Polaris is on the northern horizon. In the southern hemisphere, Polaris is not visible at all because it is below the northern horizon. Polaris is 500 light years away.

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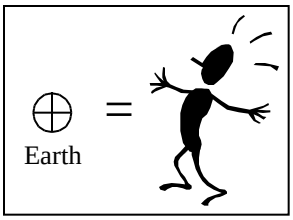
http://nationalatlas.gov/

Flagpole Diagram

(looking down on a circle of students doing Step 40)



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