Kinesthetic Astronomy™

Cherilynn Morrow and Michael Zawaski

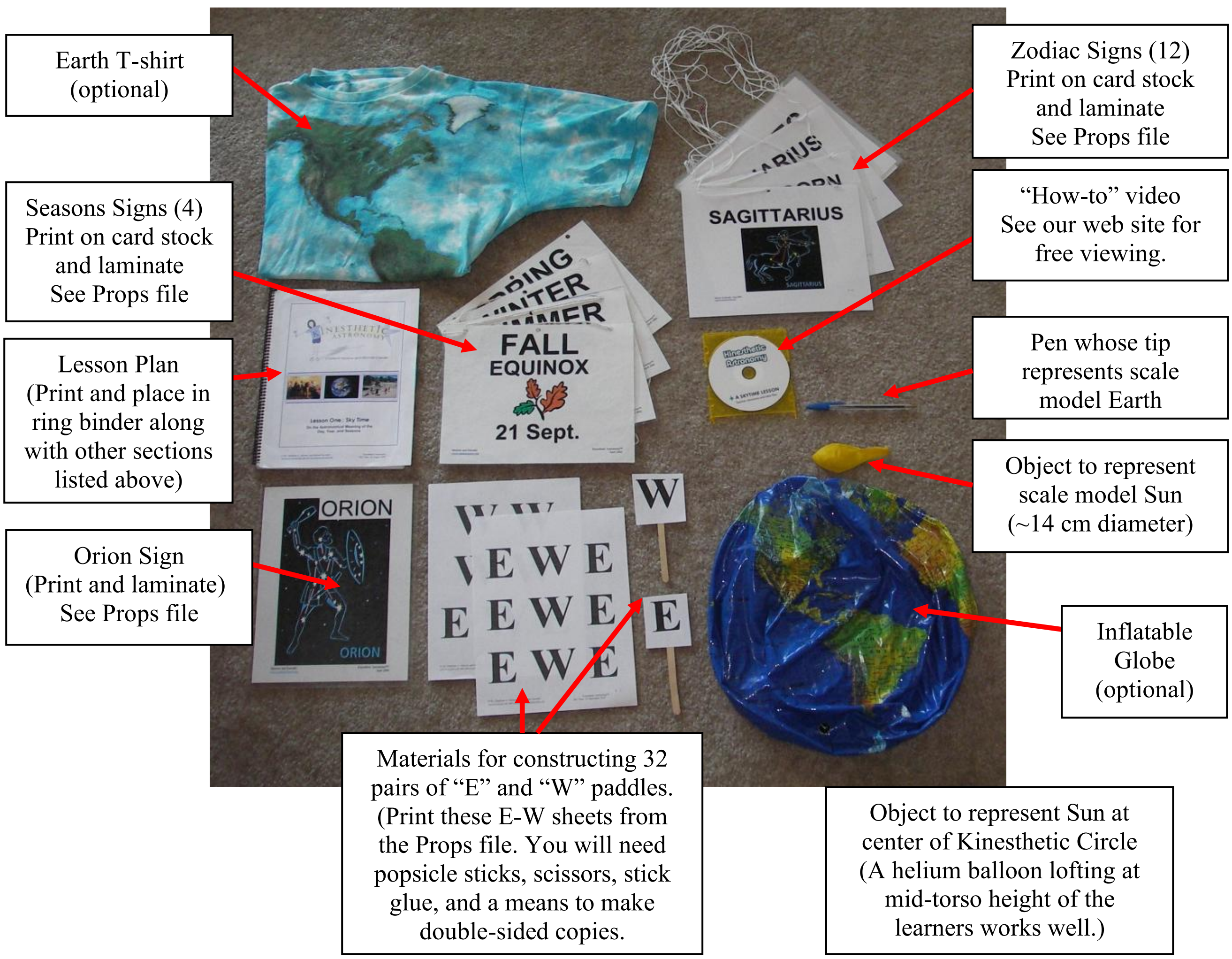
Lesson One : Sky Time

On the Astronomical Meaning of the Day, Year, and Seasons

HERE IS A GUIDE TO THE ITEMS YOU NEED TO START TEACHING KINESTHETIC ASTRONOMY™.

To see Kinesthetic Astronomy™ in action and become familiar with Sky Time:

1. Consider watching the 2-part video for educators on Vimeo created in 2010: https://vimeo.com/18066669 (Part 1 of 2). https://vimeo.com/18066936 (Part 2).
2. Use the image below to explore the lesson's resources and props.
3. Read the "Dear Educator" letter on the next page (and author's bios if you like!).
4. Review the Table of Contents, and if you are excited to teach this lesson…
5. Print out the four files and organize them in a ring binder according to the Table of Contents on p5: 1) Getting Ready, 2) The Lesson Plan, 3) Written Assessment Options, 4) Assessment Answer Keys, and 5) Props (includes instructions for constructing the "E" and "W" paddles, setting up the Kinesthetic Circle, and the printable Seasons Signs (in color) and Constellation Signs (in color).
6. Turn to the "Getting Ready" section of the lesson (p6) for guidelines on your props and setting up your teaching and learning space.



Dear Educator,

Here we present an experiential lesson we call Kinesthetic Astronomy™: The *Sky Time* lesson, *Sky Time* reconnects students with the astronomical meaning of the day, year, and seasons. Like all Kinesthetic Astronomy™ lessons, it teaches basic astronomical concepts through choreographed bodily movements and positions that provide educational sensory experiences.

Kinesthetic Astronomy™ lessons are science-rich and fun. They are intended for **sixth graders up through adult learners** in both formal and informal educational settings, and they can also be adapted for younger learners. They emphasize astronomical concepts and phenomenon that people can readily encounter in their "everyday" lives such as time, seasons, and sky motions of the Sun, Moon, stars, and planets. Kinesthetic Astronomy lesson plans are **fully aligned with research-based education standards, both in content and instructional practice**. Our lessons offer a complete learning cycle with written assessment opportunities embedded throughout.

Field testing and evaluation with non-science undergraduates, middle & high school science teachers and students, Junior girl scouts, museum education staff, and outdoor educators has been providing evidence that kinesthetic astronomy techniques allow learners to achieve a good intuitive grasp of concepts that are much more difficult to learn in more conventional ways such as via textbooks or even computer animation.

Field testing of the *Sky Time* lesson by **Clark Planetarium** and formal review by the **Utah Department of Education** has led us to significant changes from previous versions. These include: 1) adding some illustrations to help communicate the lesson's set-up more effectively; 2) strengthening the written assessment options; and 3) including answer keys for all assessments. The assessments help students to translate their kinesthetic and visual learning into the verbal-linguistic and mathematical-logical realms of expression. This improvement also enables teachers to better monitor progress in student understanding throughout the lesson.

Visit us at https://tinyurl.com/PUNCHOutreach where you will find the most up-to-date version of *Kinesthetic Astronomy* listed among the NASA PUNCH Outreach suite of well-vetted learning activities developed between 2021 and 2026. Please also consider watching the 2-part video for educators on Vimeo created in 2010: https://vimeo.com/18066669 (Part 1 of 2). https://vimeo.com/18066936 (Part 2). It is still a good orientation. Our video includes a clip from Harvard's classic video, *A Private Universe*. Please send us your photos and feedback about Kinesthetic Astronomy™. We love hearing from our fellow astronomy educators.

We hope you will enjoy our efforts to make the *Sky Time* lesson more accessible and useful to you and your students.

Cherilynn Morrow and Michael Zawaski
Boulder, CO
September 2010
March 2025: Updated Email addresses, links, and bios

Cover Photos, Graphics, and Drawings:
Left: Cherilynn 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. (Photo by Christy Edwards and Jesper Schou)
Right: Michael Zawaski leads the Sky Time lesson with students from the Eagle Rock High School (a high school for at-risk students in Estes Park, Colorado). The setting is Vedauvoo, WY. (Photo by Cherilynn Morrow)

Cover graphic rendered by Tyson Brawley. All drawings of students rendered by Andrew Sanchez.

About the Authors

The partnership of Dr. Cherilynn Morrow and Michael Zawaski began a couple of years after Mike was a student in a NASA-supported astronomy training for Outward Bound instructors implemented by Cherilynn in 1995. With outdoor educators, it was natural to begin exploring how to use the human body to learn astronomy that related to what is visible in the daytime and nighttime sky. After Mike sought further astronomy education, Cherilynn and Mike worked together to create an innovative college course called Astronomy for Outdoor Educators that relies mostly on kinesthetic teaching techniques. They have also worked successfully with at-risk students, Native Americans, and other underserved populations. Since 1998, they have taught courses and workshops that have introduced many thousands of educators and students all across the US to the joys of learning with Kinesthetic Astronomy™. As of 2025, Mike and Cherilynn continue to work together, still developing and testing innovative learning activities products for all ages as part of the NASA PUNCH Outreach project.

Dr. Cherilynn Morrow is a solar astronomer by training (PhD Astrophysical Planetary and Atmospheric Sciences, University of Colorado 1988) who chose to make a transition to science and math education. She has worked at the National Center for Atmospheric Research (NCAR), Cambridge University, NASA Headquarters, the Space Science Institute, the SETI Institute, as science faculty with Semester at Sea, and as a professor in the Physics & Astronomy department at Georgia State University. Starting in 2020 she began designing and directing the outreach program for the NASA PUNCH mission where she continues to blend art, science, and culture in service to re-connecting humans with their extraordinary cosmos.

Over the past three decades, Cherilynn has designed and implemented hundreds of professional and leadership development experiences for both scientists in education and for educators in science. She has focused considerable effort in the 4-Corners region of the US (AZ, CO, NM, UT), working with Native American educators and interpretive staff in National Parks.

Cherilynn is an accomplished developer of educational materials for middle school, undergraduate, and family learners. In addition to her work with Mike on Kinesthetic Astronomy, she led the development of the Family Guide to the Sun, The Family Guide to Mars, the Saturn Educator Guide for NASA's Cassini Project, and the NASA PUNCH Outreach suite of products aligned with the Ancient and Modern Sun-watching theme (created in partnership with a multi-institutional, multicultural Collaborative).

Cherilynn's personal interests include yoga, meditation, hiking, e-biking, exploring across cultures, dancing, singing, and inventing songs on an Native American flute.

Dr. Mike Zawaski has built a unique synthesis of experience in scientific research, science education, and outdoor education. His 21 years of instructing and course directing for Outward Bound taken him up glaciated mountains, guiding multi-pitch rock climbs, rafting rivers, backpacking through canyons, and kayaking the ocean. Mike continues to climb, mountain bike, hike, ski, and explore wild places.

In 2007, Mike earned an MS in Earth Sciences from the University of Northern Colorado. His dissertation research involved surveying Peruvian Inca monuments for their astronomical alignments.

In 2021, Mike completed a PhD in Geosciences from the University of Colorado. His research involves interpreting rocks in a variety of geological contexts, including searching for evidence of life in some of Earth's oldest rocks and studying modern sand dunes as analogs for wind-blown processes on Mars. In 2024, Mike finished a 2.5-year postdoc as a geologist on the Mars2020 mission's Perseverance Rover.

Mike has taught college courses in geology, astronomy, and meteorology since 2008. Colleges include CU Boulder, Western Colorado University, and Front Range Community College. Mike is currently on the faculty at Fort Lewis College.

Since 2000, Mike has served as an instructor for the Wilderness Medicine Institute of NOLS. Since 2021, he has been co-developing and field-testing learning activities and videos as a member of the NASA PUNCH Outreach team.

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https://tinyurl.com/PUNCHOutreach
Click on *Kinesthetic Astronomy*

ACKNOWLEDGEMENTS: We acknowledge the NASA IDEAS program for the initial seed funding that led to the further development of the *Sky Time* lesson. We also acknowledge the staff of the Space Science Institute (Boulder, CO) for their support. We wish to express special thanks to the able educators and learners who have worked with us and inspired us to constantly improve *Kinesthetic Astronomy* and the *Sky Time* lesson. Their names are too numerous to list, but some of their organizations are: Clark Planetarium (Salt Lake City), Sunset Middle School (Longmont, CO), Eagle Rock High School (Estes Park, CO), Western Colorado University (Gunnison, CO), Outward Bound West (Golden CO), the National Outdoor Leadership School (Lander, WY), the Mile-Hi Girl Scout Council (Denver, CO), the Fiske Planetarium (Boulder, CO), Project ASTRO and the Astronomical Society of the Pacific (San Francisco, CA) National Optical Astronomy Observatories (Tucson, AZ), the Aspen Center for Environmental Studies, the Exploratorium (San Francisco), the Denver Museum of Nature and Science, the Boston Museum, the Harvard-Smithsonian Center for Astrophysics (Boston), Flashback Video Productions (Boulder, CO), the Society for Advancement of Chicanos and Native Americans in Science (Albuquerque, NM), the University of Arizona and University of Wyoming, the Space Foundation (Colorado Springs), and Chaco Culture National Historical Park (New Mexico).

cherilynn.morrow@gmail.com and mjzawaski@gmail.com

SKY TIME: On the Astronomical Meaning of the Day, Year, and Seasons

GETTING READY

LESSON DESCRIPTION:
Modern everyday association with time involves watches, clocks, and calendars instead of the astronomical motions that were the original bases for time keeping. Through a series of simple body movements, students gain insight into the relationship between time and astronomical motions of Earth (rotation about its axis, and orbit around the Sun), and also about how these motions influence what we see in the sky at various times of the day and year. The lesson can be applied to understand the times of day and year on other planets (e.g. Mars). The lesson can be taught with or without an emphasis on the *reasons for seasons*, but in any case is an excellent set-up for understanding seasons.

AUDIENCE: Middle school ages and up.

LOCATION/SETTING:
An indoor or outdoor space large enough for your students to form a circle with arms outstretched to their sides. For a class of 25-30 students one needs a space whose size is about half a basketball court. This lesson is best with at least eight students participating.

TIME TO IMPLEMENT: 3-6 hours, depending on prior knowledge of students and choice of assessments.

PREREQUISITE SKILLS and KNOWLEDGE:
1. Has observed the daily motion of the Sun in the sky
2. Knows the location of Earth's poles and equator
3. Is familiar with the latitude and longitude coordinate system on Earth
4. Has observed that the Sun is higher in the sky in summer and lower in the sky in winter
5. Is familiar with the terms "solstice" and "equinox" and their calendar dates
6. Knows that stars appear in fixed patterns called "constellations"
7. Knows the difference between a star and a planet
8. Knows that there are 360 degrees in a circle and how to estimate 45º and 90º angles

EDUCATION STANDARDS and BENCHMARKS:
(Grades 5-8) Earth and Space Science: 1) Knows the positions of the Sun and Earth in the Universe; and
2) Knows how the regular and predictable motions of the Sun and Earth are related to the day and the year.

SPECIFIC LEARNING GOALS:
1. Explain a proper size and distance scale for the Sun, Earth, and the nearest star.
2. Describe and demonstrate how Earth's rotation about its north-south axis and Earth's orbit of the Sun are related to the day and the year on Earth. Be able to apply the astronomical meaning of a day and year to other planets, including correct use of the terms "rotation" and "orbit".
3. Explain why the Sun appears to rise and set, and know how to determine that the constellations of stars rise and set like the Sun due to Earth's rotation.
4. Describe how the constant tilt of Earth's North Pole toward the distant star Polaris (the North Star) affects the orientation of Earth's hemispheres toward or away from the Sun at different times of year.
5. Demonstrate why we see different constellations in the night sky at different times of the year.
6. Reason correctly in addressing the question of whether people in the US tonight will see the same stars as people in China saw last night (assuming everyone is observing from the same latitude).
7. Demonstrate why the constant tilt of Earth's axis toward Polaris results in the Sun being higher in the sky in summer and lower in the sky in winter, and why this results in Earth's seasons. Be able to apply this understanding to another planet like Mars. *(Optional: only if teaching the lesson with an emphasis on the **reasons** for seasons.)*

MATERIALS and PREPARATION

Refers to **"P" pages** (in Props file) and **"ST" pages** (in Assessment Options file) appended to the lesson

Props for the kinesthetic learning environment

1. A spherical object the size of a large grapefruit (14-cm diameter for scale model Sun)
2. A ball point pen or pencil (tip is for scale model Earth)
3. An object to represent the Sun at the center of the circle (a lofting helium balloon is ideal)
4. 12 Zodiac Signs with instructions for assembly and set-up **[P 9 – P 22]** (Masking tape is needed if you are taping these signs to chairs or walls. Best to laminate and attach strings for repeated use.) Use of the sign representing the Orion constellation **[P 23]** is optional (used with **ST 20**)
5. A sphere to show the distribution of continents on planet Earth (globe or inflatable Earth)
6. A T-shirt with North & South America on the front and Asia & Australia *(Optional)*
7. Birthday or party hat (*Optional, but a simple and fun enrichment*)
8. 4 Seasons Signs with dates of equinoxes and solstices [**P 5 to P 8**] (laminate for repeated use)
9. Flashlight or light source that projects a bright beam of light *(Optional: only if you choose to emphasize the reasons for seasons. The lesson can be taught with or without this emphasis)*

For each student: during kinesthetic activities

10. A pair of "E" and "W" cards [see **P 2 to P 4** for assembly] (*Optional*: Similar objects or hand gestures can also be used to indicate direction – not recommended for younger students.)

For each student: written assessment options (1 pre-, 1 post-, and 14 embedded)

1. "What do You Know?" – Pre-assessment questionnaire **[ST 2 – ST 4]**
2. "Scale Model of the Sun, Earth and Moon" – Cutout Activity **[ST 5]**
3. "Exploring the Structure of the Universe" – Fill-in-the-Blank **[ST 6]**
4. "Body Geography" – Student Worksheet **[ST 7]**
5. "Kinesthetic Times of the Day" – Student Worksheet **[ST 8]**
6. "Rotation vs. Orbit" – Student Worksheet **[ST 9]**
7. "The 'Dating' Game" – Student Worksheet **[ST 10]**
8. "Kinesthetic Seasons" – Student Worksheet **[ST 11]* (* = emphasis on reasons for seasons)**
9. "Reasons-for-Seasons Concept Map Activity" **[ST 12 – ST 13]***
10. "Reasons-for-Seasons" – Fill-in-the-Blank **[ST 14 – ST 15]***
11. "Your Birthday Stars" – Student Worksheet **[ST 16 – ST 17]**
12. "Different Stars for Different Seasons" – Fill-in-the-Poem **[ST 18]**
13. "The Night Sky in China" – Student Worksheet **[ST 19]**
14. "Who Can See Orion When?" –Student Worksheet **[ST 20]**
15. "Comparing Seasons on Earth and Mars" – Worksheet **[ST 21]***
16. "What Have You Learned?" – A Cumulative Post-Lesson Assessment Tool **[ST 22 – ST 26]**

BACKGROUND AND COMMON MISCONCEPTIONS

Kinesthetic describes a sensation of bodily position, presence, or movement. Putting a spoonful of soup in our mouth is an everyday example of using a kinesthetic sense. We know where our mouth is even though we do not see it or touch it. We kinesthetically sense the presence and position of our mouth so that the soup spoon makes it in. You can kinesthetically sense the position and movement of other body parts as well. The Sky Time lesson calls on our kinesthetic senses as we rotate, bend, and tilt to learn basic astronomical concepts. A section of Frequently Asked Questions (FAQ) that have arisen during field testing is located at the end of this lesson. Below, we also note several common misconceptions that have been encountered during field testing of this lesson.

1. Many people think that there is more than one star in our solar system and that the Solar System is the entire Universe. For example, many wrongly think that Polaris (the Pole Star or North Star) is within the Solar System and closer than the planet Pluto. In reality Polaris is about 876,000 times more distant from our sun than Pluto. We thus strongly recommend emphasis on scale and basic structure of the Universe as required pre-requisites to the Sky Time lesson (e.g. Scale Model of the Sun, Earth, Moon & Nearest Star **[ST 5]** and the "Structure of the Universe" Fill-in-the-Blank **[ST 6]**.

2. Many people (except those who have watched the night sky for hours) have not perceived that stars (at all but polar latitudes) appear to rise and set just as the Sun does (due to Earth's rotation about its north-south axis). For some urban dwellers, even sunrise and sunset are uncommon experiences.

3. *NSF Indicators of Science & Engineering 2002* reports that about 50% of a representative sample of the U.S. public are unaware that it takes one year for Earth to orbit the Sun.

4. There is a common confusion between use of the terms "rotation" and "orbit". "Rotation" is often <u>mistakenly</u> used to describe the motion of Earth orbiting the Sun. It is important to make the distinction between these terms very clear. Each day Earth *rotates* once on its axis; each year Earth *orbits* the Sun. The term "revolution" is out-dated, but still in use to mean the same thing as "orbit".

5. When asked whether people in China will see the same stars tonight as people in the US (if both are located at about the same latitude), many people answer "no". Earth's rotation makes noon change to midnight, and this takes only twelve hours. Earth's orbit around the Sun slowly changes the direction Earth's night side faces out into space. Meanwhile, in 12 hours Earth has not moved very much in its orbit around the Sun, and so the night side in China is facing almost the same direction out into space as the night side in the US. Thus the people in China will see the same stars tonight.

6. A common misconception is that Earth has seasons because Earth's tilt "changes" as Earth moves in orbit around the Sun and so they imagine Earth *wobbling* as it moves about the Sun. In fact, Earth's tilt remains steady toward Polaris throughout Earth's orbit. The lesson below helps participants experience how Earth's rotation axis can have a different orientation *with respect to the Sun* just by keeping its North Pole pointed toward the star Polaris as it moves around the Sun. Of course, Earth's axis *does* wobble. It's called precession, but it takes 26,000 years for it to wobble once around. This wobble is negligible over a year's time.

7. By far the most common misconception is that Earth's 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 (summer in the southern). For Earth, it is only the effects of the constant tilt toward Polaris combined with Earth's orbital motion that give us seasonal changes. The orbit of Mars, however, is more elliptical, and so in this case the distance to the Sun *does* matter just as much as the tilt of Mars rotation axis.

THE "SKY TIME" LESSON PLAN

The Sky Time lesson has five major sections designed to support a constructivist, inquiry-based approach to teaching and learning that is aligned with Standards for science education: 1) Engagement and Assessment of Prior Knowledge; 2) Lesson Activities and Applications; 3) Lesson Extensions; 4) References and Resources; and 5) Frequently Asked Questions.

I. ENGAGEMENT and ASSESSMENT of PRIOR KNOWLEDGE

The questions on the pre-assessment questionnaire ["What Do You Know?" **ST 2 – ST 4**] elicit students' prior knowledge related to sky motions, Earth rotation & orbit, seasons, and what we can see in the sky at different times of day and year. Give students at least 30 minutes to complete the questionnaire. Before moving on to the rest of the Sky Time lesson, examine the questionnaire results for missing pre-requisite knowledge and for any misconceptions related to lesson content. Save the un-graded pre-assessment questionnaires to compare to post-lesson assessment results ["What Have You Learned?" **ST 22 – ST 26**].

Use the lesson's activities and experiences to assist students in confronting and resolving their misconceptions. Use interim worksheets **[ST 5 – ST 21]** to allow students to reflect on how their prior knowledge is being changed or extended by the lesson and to help translate their kinesthetic and visual learning to the verbal-linguistic and mathematical-logical realms of expression.

II. LESSON ACTIVITIES and APPLICATIONS

The full outline of this section is provided below. There are a variety of written worksheets and assessments available to re-enforce the content and monitor student learning. These resources are noted by references to "ST" pages which are in the file named "KA-Assessment Options". The answer key for all the assessment options are in the file named, "KA-Assessment Answer Key".

IIa. The Set-up for Kinesthetic Astronomy

i. The Proper Size-Distance Scale for the Sun, Earth, Moon and Stars **[ST 5 – ST 6]**
ii. The Kinesthetic Astronomy Circle (emphasize circle)
iii. Body Geography: Our Bodies as Planet Earth **[ST 7]**

IIb. The Astronomical Meaning of Day and Night

i. Earth's Rotation & Times of Day (construct meaning of "rotational period") **[ST 9]**
ii. Do Stars Appear to Rise and Set?
iii. Adding Earth's Tilt to the Kinesthetic Day

IIc. The Astronomical Meaning of a Year

i. Earth's Orbit of the Sun (construct meaning of "orbital period") **[ST 9]**
ii. Adding Earth's Tilt to Identify Winter & Summer **[ST 10]**
iii. Insights on the Reasons for Seasons* (reasons for seasons emphasis: **[ST 11 – ST 15]**)
iv. Finding the Equinoxes and Everyone's Birthday
v. What Does it Mean to "be a Leo"? – Different Stars for Different Seasons **[ST 16 – ST 18]**
vi. Kinesthetic Birthdays: Tilt, Rotation and Orbit

IId. Applying/Assessing New Knowledge about the Day and Year

i. Will We See the Same Stars in the US Tonight that People in China Saw Last Night? **[ST 19]**
ii. Who Can See Orion When? **[ST 20]**
iii. Comparing Seasons on Earth & Mars* (reasons for seasons emphasis **[ST 21]**)
iv. What Have We Learned? – A Cumulative Post-Lesson Assessment Tool **[ST 22 – ST 26]**

IIa. The Set-up for Kinesthetic Astronomy [refers to ST 5 – ST 7]

This section leads you through the basic set up for the Sky Time lesson. After establishing the Kinesthetic Circle, we use Body Geography to explain how the students' own bodies can represent planet Earth. The Kinesthetic Circle has enormous potential for teaching and learning, but it is *essential* to preface all Kinesthetic Astronomy lessons with a scale model of the Sun, Earth, and the nearest star to our Sun (see below). Otherwise the set-up can cause students to absorb very wrong ideas about the relative sizes and distances of the Sun, Earth, and stars.

The Proper Size-Distance Scale for the Sun, Earth, Moon and Stars [ST 5 - ST 6]

1. Gather students at one end of a space at least 50 feet long. Use an object the size of a large grapefruit to represent the size of the Sun (of course it is really 10 billion times bigger around). Ask students to use their hands to predict how big Earth would be compared to the grapefruit on this 1:10 billion scale.

2. When students have shown you their predicted sizes of Earth, tell them that on this scale Earth would only be as big as the tip of a ballpoint pen. [The Sun has a diameter 100 times that of Earth.] Next, ask students to walk as far away from the grapefruit Sun as they predict the pen-tip Earth would be located in the scale model.

3. When students have arrived at their predicted locations, pace out the 15 meters (50 feet) to where Earth belongs. Gather the class around you and explain that in the scale model, Earth would be 15 meters away. [The actual Earth-Sun distance is 150 million km (93 million miles).] Also tell them that the planet Pluto would be 0.5 mile away.

4. Ask: "What is the next closest star to our Sun?" [Alpha Centauri]. "How far is this star is from our Sun?" [4.3 light-years]. NOTE: a "light-year" is the distance light travels in one year = 10 trillion km = 6 trillion miles.

5. Tell students to assume that the grapefruit Sun is located in California. Ask: "In the scale model, where would the next "grapefruit" (Alpha Centauri) be?" [The nearest star would be represented by another grapefruit 4 MILLION meters (2500 miles) away. That's like having the grapefruit-Sun in California and the grapefruit-nearest star in New York!

Object	Scaled Diameter	Scaled Distance from the Sun
Sun	14 cm = large grapefruit	0
Earth	1.3 mm = tip of ballpoint pen	15 meters (50 feet)
Alpha Centauri	14 cm = large grapefruit	4×10^6 meters (2500 miles)

6. Tell students that the Sun and Alpha Centauri are only two of 100 billion stars in our galaxy called the Milky Way, and that the Milky Way is one of 100 billion galaxies in a very large Universe.

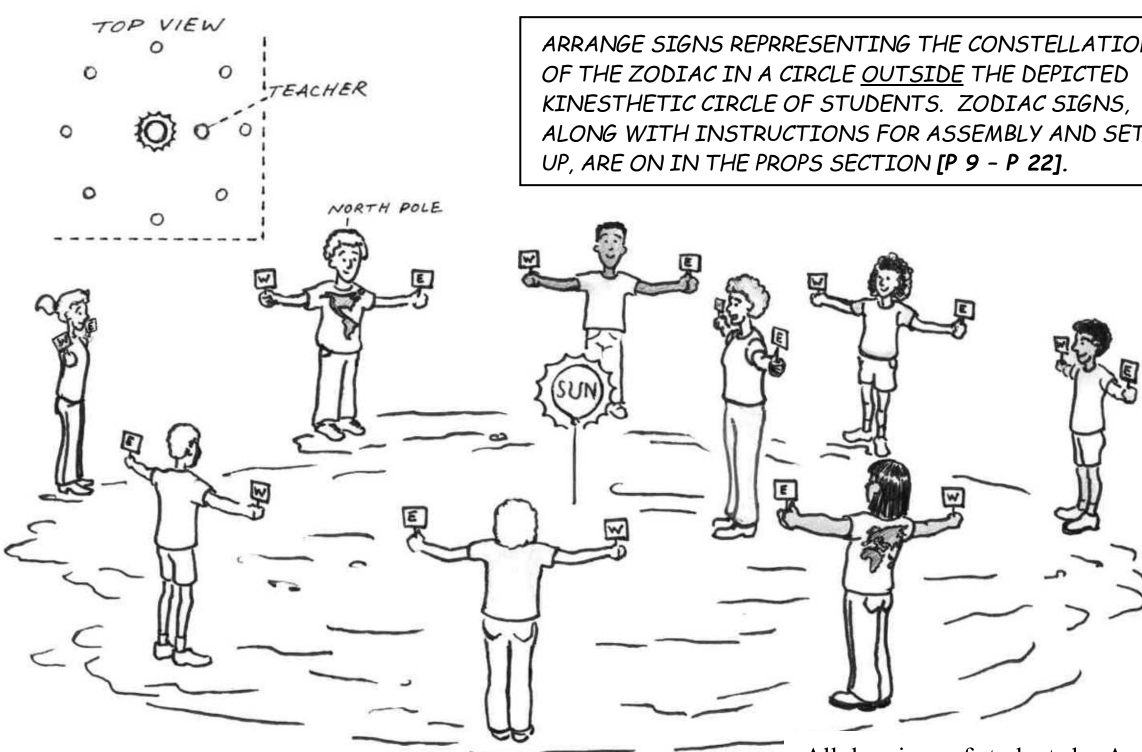
7. Give students the **"Scale Model of the Sun, Earth, Moon" Cutout Activity [ST 5]** and the **"Exploring the Structure of the Universe" Fill-in-the-Blank [ST 6]** as homework or in-class assessment activities.

The Kinesthetic Astronomy Circle

8. Signs representing the constellations of the Zodiac should be assembled and placed before students arrive. Instructions are in the Props Section **[P 9 – P 22]**. A helium balloon lofting at the height of an average students' solar plexus (where the chest meets the belly) is ideal to represent the symbolic Sun at the center.

9. Ask students to arrange themselves in a circle around the central object representing the Sun. This Kinesthetic Circle of students should be inside the ring of signs representing the Zodiac constellations (not depicted below). Students should have room to rotate with their arms outstretched to the sides.

ARRANGE SIGNS REPRRESENTING THE CONSTELLATIONS OF THE ZODIAC IN A CIRCLE OUTSIDE THE DEPICTED KINESTHETIC CIRCLE OF STUDENTS. ZODIAC SIGNS, ALONG WITH INSTRUCTIONS FOR ASSEMBLY AND SET UP, ARE ON IN THE PROPS SECTION ***[P 9 – P 22].***



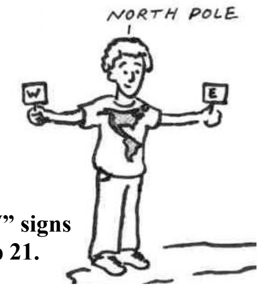
All drawings of students by Andrew Sanchez

10. Tell students that each of their bodies represents planet Earth. Point out the symbolic Sun at the center and the signs representing the constellations of the Zodiac (the Zodiac signs are not depicted above).

11. Ask: "Is this set up of Earth-Sun and stars to scale?" Guide student thinking with follow-up questions: "Is Earth as large as our bodies compared to the Sun?" Is Earth this close to the Sun? Are the stars this close to the Sun and Earth?" [No. Remind students of the true scale model with the grapefruit "Sun" and pen-tip "Earth" located 50 ft (15 m) away.]

Body Geography: Our Bodies as Planet Earth [ST 7]

12. Students should be standing around the Kinesthetic Circle, facing the center. Remind students that each of their bodies represents the entire planet Earth.



NOTE: The "E" and "W" signs are not needed until Step 21.

13. Ask students to touch their "North Pole". [Top of their head.]

14. Tell students their "South Pole" is located at the bottom of their spine – their tailbones.

15. Ask: "Where is the equator?" [Where the chest meets the belly; encircling the body.]

16. Ask: "What <u>hemisphere</u> is above the equator?" [Northern] "What hemisphere is below the equator?" [Southern]

17. Tell students to imagine that North America is located on their chest. Have students put one hand on their "North America".

18. Ask students to touch their "South America"? [Lower left belly]

19. Gesture toward your upper back and ask: "What is on the other side of Earth from North America? [China, Asia.]

20. Ask: "Where is Australia?" [Lower right back – "Down Under".]

21. Give each student both an "E" and "W" sign [See **P2 – P4** for assembly instructions].

22. *Optional*: Ask one of your students to put on an Earth T-shirt with North and South America on the front and China and Australia on the back.

23. Remind students that North America is on their chest. Ask: "Which of your hands is eastward (towards New York on the US map) and which is westward (towards California on the US map)?" Give students a minute or so to think and discuss with neighbors.

24. Tell students to put their "E" sign in their "eastward" hand and the "W" sign in their "westward" hand. [Students should have their "E" in their left hand to indicate an eastward direction and their "W" in their right to indicate westward.]

TEACHER TIP: Be alert for students who are having trouble visualizing which way is eastward and reversing the "E" and "W" signs. It is very valuable to have a globe or inflatable Earth that can be placed at any students' belly with the US facing outward. Students can look down and see which arm is extending toward NY and which arm is extending toward California.

25. Give students the **"Body Geography" Student Worksheet [ST 7]** as homework or an in-class assessment activity.

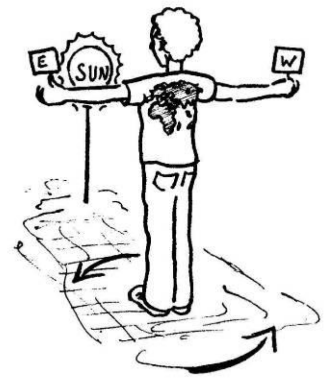
IIb. The Astronomical Meaning of Day and Night [ST 8]

This section begins with making the connection between Earth's rotation and the times of day. It demonstrates why the Sun appears to rise in the east and set in the west and how different parts of Earth can experience different times of day at the same moment. The section goes on to explore whether stars rise and set. The section finale challenges students to add the tilt of Earth's axis toward Polaris into their kinesthetic rotation. <u>For all subsections, students should be at noon around the Kinesthetic Circle with "E" and "W" signs in hand and the Zodiac ring in place.</u>

<u>Earth's Rotation & Times of Day [ST 8]</u>

26. Ask: "How does the Sun appear to move in the sky?" [Rises in the east; Sets in the west.]

27. Have students face directly toward the symbolic Sun with their arms outstretched – "E" in the left hand and "W" in the right hand. Ask: "What time would it be along a line that runs down the middle of the front of you?" (Gesture with a karate-chop motion of your hand from the middle of your face down along the front of you) [Noon or Midday.]



28. Ask: "Why is it midday?" [The Sun is midway between east and west.]

29. Tell students: "The line that runs north-south, midway between your east and west is called your ***meridian.***" Ask everyone to show you their meridian. [Hands moving up and down the middle of the front of their bodies.]

30. Tell students: "When the Sun is directly out in front of you at noon, it is 'on your meridian'".

31. Have students face directly away from the Sun with their arms outstretched to the sides. Ask them: "Is the Sun on your meridian?" [No] Ask: "What time is it at your meridian?" [Midnight] "What would you see?" [Stars]

32. While students are still in their midnight positions, ask: "What time is it along a line that runs along the middle of your back?" [Noon] "What would people there see in the sky? [The Sun]

33. Call students' attention to how it can be different times at different places on Earth, and how there are 12 hours between their front and back.

34. Return students to face the Sun (i.e. "noon" or "midday at their meridian"). With arms outstretched, have students look down along their "E" arm. Tell them that the student to their left is "low in their east."

35. Next have students look down their "W" arm. Tell them that the student to their right is "low in their west."

36. Demonstrate to students that what is visible to them at any given time includes what can be seen down along their "E" arm, panning out in front of them through their meridian, and over to looking down along their "W" arm. What's behind their arms is out of sight.

37. Have students make a 90-degree turn toward their east (toward their "E" arm). Ask: "What is low in your east?" [A constellation of the Zodiac.] "What is low in your west?" [The Sun]

38. Ask: "What time of day is this when the Sun is low in your west?" [Sunset]

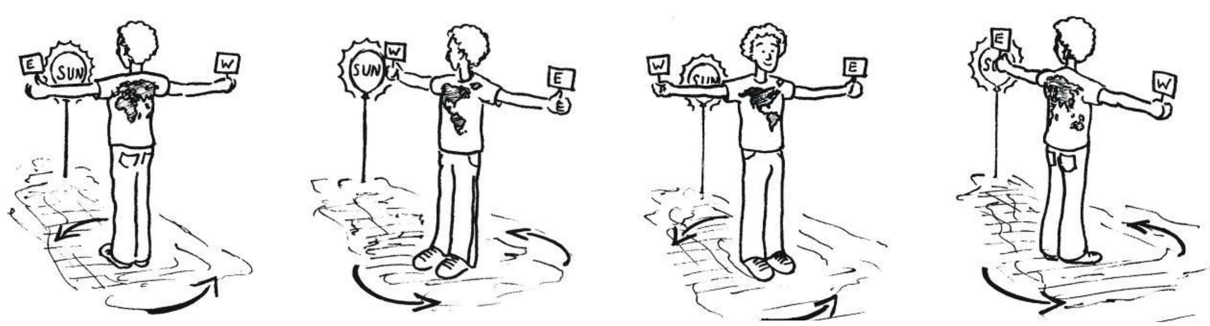
39. Ask: "Why is this sunset?" [Because the Sun is disappearing in the west.] Remind students that they can turn their head to look down their arm and see the Sun low in their western sky.

40. Ask: "Why does the Sun seem to disappear in the west?" [Because I turn away from it.]

41. Ask: "Does the Sun set at the same time everyday of the year?" [No, the Sun sets earlier in the winter and later in the summer.] Tell students to use a time in-between for sunset = 6pm.

42. Return to noon. Ask: "So which way does Earth turn so that the Sun appears to set in the west and rise in the east (i.e. re-appear in front of their outstretched "East" (left) hand as they continue to turn). Give students time to work out the answer, using trial and error if need be. Give them a minute or so to compare their thoughts with their neighbors.

43. Now guide everyone in rotating through a complete day. Start with the noon position, facing the Sun. Command students in sequence:
- "Go to sunset." Ask: "About what time is this?" [~ 6 pm]
- "Go to midnight." Ask: "What do you see in your sky?" [Stars]
- "Come to sunrise." Ask: "What do you see in your sky?" [The Sun low in the east.] Remind students to look out along both arms as well as in between. "About what time is this?" [~ 6 am]



NOON SUNSET MIDNIGHT SUNRISE

44. Return to noon. Ask: "What do we call this turning of Earth that causes the Sun to rise and set?" [Rotation.] <u>Define and demonstrate</u> the term "Rotation" as the spin of a body around an axis, just as students spin around the axis of their bodies with their heads as North Poles.

45. Ask: “How long does it take Earth to rotate around one time?” [24 hours = 1 day]

46. Define the term “Rotational Period” as the *time* it takes a body to spin on its axis.

TEACHER TIP: As enrichment, you may alert students to the enjoyment of trying to “sense” Earth’s rotation during a sunrise or sunset. For example, when the Sun is low in the east, its apparent rising motion seems more rapid because you have the horizon as a reference to measure its progress. It is then fun to try to reverse the usual perception of the Sun moving, and instead try to perceive Earth turning toward the East thus making the Sun appear to rise.

47. Confirm that students are relating Earth’s rotation to different times of day. Have them start at noon with outstretched arms and then make a 45° turn toward the east. [This is midway between noon and sunset, and students often need a reminder not to turn 90° to sunset.]

48. Ask: “What time of day is this for you?” If needed, follow up with: “Is it before or after noon?” [After noon.] “Is it before or after sunset?” [Before] “So about what time is it?” [About 3pm.] “Is the Sun in the eastern or western sky?” [Western]

49. Tell students: “Go to 3am.” If needed, follow up with: “Is it before or after midnight?” [After.] “Is it before or after sunrise?” [Before] [Students turn to the east (left), until facing about 45° past midnight.]

50. Have students return to 3pm. Ask: “What is the time along a line down the middle of the back of you, say in China?” [3am – twelve hours later.]

51. Ask: “What is today’s date in the US at 3pm?” “What would be the date in central China where it is 3am?” [Tomorrow’s date.]

52. Have students complete the worksheet **“Kinesthetic Times of the Day” [ST 8]** as homework or in-class assessment.

<u>Do Stars Appear to Rise and Set?</u>

53. Ask: “What do we call the patterns of stars we see in the sky?” [Constellations] “What are some examples of constellations?” [Orion, Big Dipper, Zodiac names like Leo and Scorpius.]

54. Ask: “Between what times of day do we see stars other than the Sun?” [After sunset until before sunrise.] “Why?” [The sky is dark – the Sun is not visible.]

55. Ask: “Will these stars and constellations appear to rise and set?” [Show of hands: “yes” or “no”. Most students respond with “no”, and if queried will explain that the stars are “fixed”.]

56. Have students rotate *just past* the sunset position. [The Sun is out of view behind their right (west) hand.]

57. While at the sunset position, have students turn their head and choose a constellation sign (or other object in the learning environment) that is low in their eastern sky (down the “E” arm).

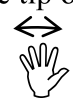
58. Have students *slowly* rotate to midnight and pause. Ask: "What happened to your chosen constellation?" "Is it still low in the east?" [No. It's in front of me…on my meridian.]

59. Have students rotate slowly onward from midnight to sunrise while keeping an eye on their chosen constellation. Ask: "Where is your constellation now?" [Low in my west.]

60. Return to noon position. Ask again: "Do stars appear to rise and set?" [Show of hands: "yes" or "no". Many more students should indicate "yes". If not, then repeat Steps 56-60.]

61. Ask: "Why do the stars appear to rise and set?" [Because Earth rotates. The same reason as the Sun appears to rise and set.]

62. Invite students to observe the motion of the stars at night and report their observations. Just after dark they can use where the sun has set or Polaris to tell directions (N, S, E, and W). Tell them to notice where a constellation or bright star is relative to some earthly feature such as a building, tree top, or ridge. Then before they go to bed, they can look again to see how the constellation or star has "moved" in the sky. Camping trips are great for this making this observation! [The Sun and stars appear to move at the rate of Earth's rotation = 15° per hour, which is the same thing as "360° per 24 hours". This amount of movement can be estimated by an open hand <u>with arm outstretched</u>: Fifteen degrees of arc in the sky is about the distance between the tip of the index finger and the tip of the pinky finger with the hand spread open.]



15° of arc with arm outstretched toward the sky

> **TEACHER TIP:** Four questions often arise during this part of the lesson: FAQ 1: Do the stars themselves move? FAQ 2: How do we explain the motion of stars that do not appear to rise or set but that can be seen all night and all year round (such as the Big Dipper)? 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? FAQ 4: If the Sun is a star, why is it so much brighter than the other stars? *Answers appear in the FAQ section – Section V of the Lesson Plan.*

<u>Adding Earth's Tilt to the Kinesthetic Day</u>

63. Ask: "We've been rotating about an axis that is straight up and down (perpendicular) relative to the Sun-Earth plane. Is that how it really is?" [No, it is tilted.]

64. Ask: "What is it tilted toward?" [Polaris/Pole Star/North Star – Students are often unaware of this fact, so you may have to explain that Earth's North Pole is tilted toward the North Star.]

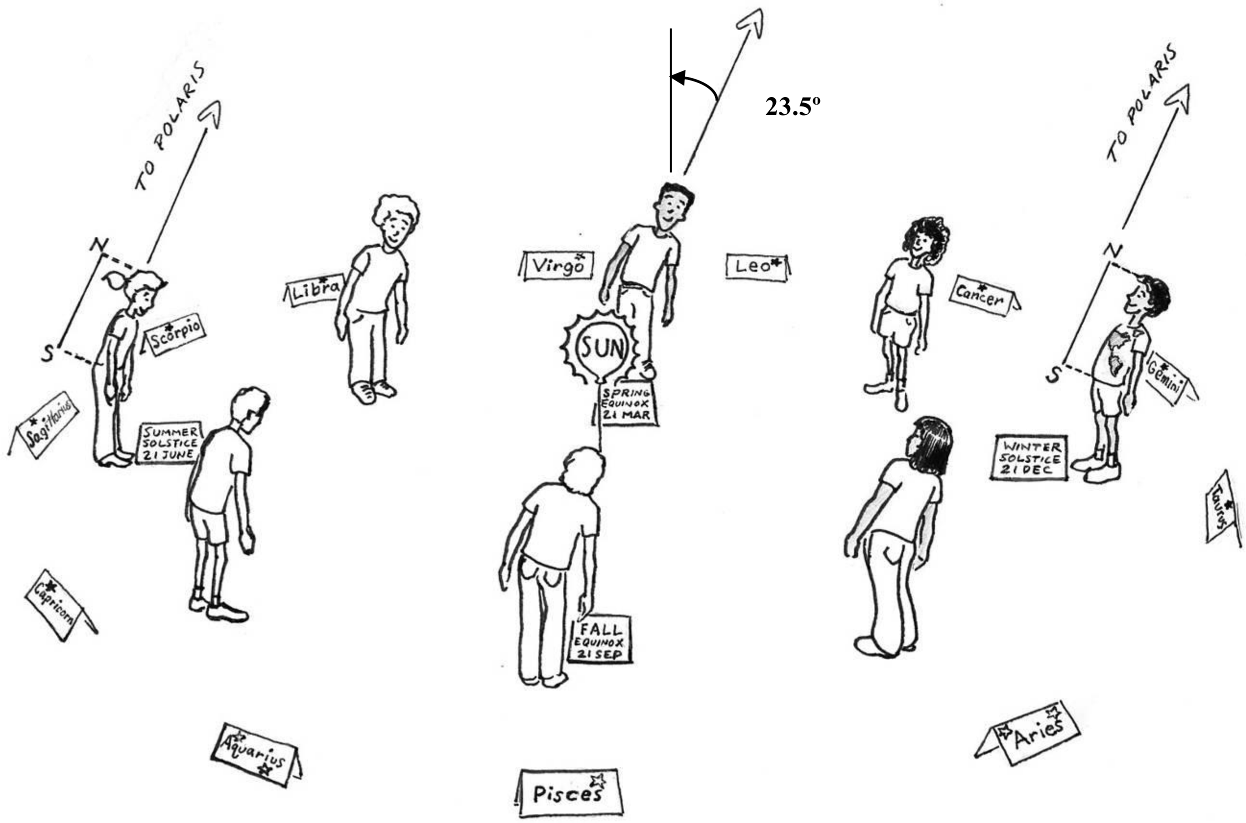
65. Tell students that Polaris is 500 light years away. This is about 876,000 times more distant than Pluto – the farthest planet from the Sun in our solar system).

66. Ask: "How much is Earth's axis tilted from the vertical?" [23.5°]

67. Tell students the direction you have chosen to represent Polaris. Demonstrate the proper direction and amount of tilt, either using your own body or a spherical model of Earth. [Show students bends of 90º and 45º so they can see how 23.5 º is about half of a 45º bend.]

cherilynn.morrow@gmail.com and mjzawaski@gmail.com

68. Tell students that Polaris is so distant that all tilts will be essentially parallel to one another rather than converging on a particular point (see diagram below).



TEACHER TIP: As tempting as it may be, do NOT use the *local* position of Polaris in the sky as an object to tilt toward. The position of Polaris in the sky depends on latitude [see FAQ 5], but the students are embodying the whole Earth and so cannot be at a particular latitude. Students should not tilt more than 23 degrees or so from the vertical no matter where on Earth the lesson is taking place.

69. Have all students face the Sun (midday-on-your-meridian). Have everyone tilt their bodies at the waist about 23.5° from the vertical so that all students are oriented toward the direction that you have chosen to be toward the distant star Polaris. [Depending on their position in the circle, students will be doing back bends, forward bends, side bends, and yet others will have to do various blends of these bends (see diagram above).]

70. Look around the circle to see that all students are in a proper tilt. Make adjustments.

TEACHER TIP: Occasionally there are students who struggle to kinesthetically sense the difference between tilting their head versus bending at the waist with their heads square over their shoulders. You can assist them in the same spirit that a gymnastic coach or yoga teacher might use to correct bodily alignment. Gently place your fingertips on each side of their head and coax it back to being square over their shoulders. Then gently, but firmly place your hands on either side of their waist and coax it to bend in the appropriate direction. The sensation of your hands helps the student to become more kinesthetically aware of the body parts you touch.

71. Have all students to try to rotate their bodies through a complete day in the appropriate direction (toward the east) around their *tilted* axis. Guide students to keep the tops of their heads oriented in the same direction toward Polaris. Give students 30 seconds or so to enjoy exploring this on their own. [This action is physically challenging, requiring changes in the bend at the waist. It generally does not go well on the first try but students enjoy trying it.]

72. Lead students through a tilted rotation in stages where you can more easily monitor whether bends at the waist are being adjusted to maintain the proper orientation toward Polaris. Have all students start at noon with arms outstretched and an appropriate tilt toward Polaris:

    - Have students slowly rotate from noon to sunset. Pause to provide needed adjustments.
    - Have them slowly rotate to midnight and pause [e.g. a forward bend at noon should have evolved to a backward bend at midnight and vice versa.]
    - Have them rotate to sunrise and pause.
    - Have all students rotate back to noon [they should be back to their original bend].

73. Demonstrate a bodily rotation with a proper tilt (this can be you or a student model).

74. Have students try their tilted day once again in a more continuous fashion. [Guide students to rotate toward their east and to maintain their orientation toward Polaris.]

75. Call the students to order (midday at their meridian). Ask: "How much time does it take Earth to rotate once around its axis? [24 hours or 1 day] Remind students that this time is called the "rotational period" of Earth.

IIc. The Astronomical Meaning of a Year [ST 9 – ST 18]

This part of the Sky Time lesson uses kinesthetic techniques to introduce Earth's orbit around the Sun and to construct the meaning of "orbital period." Students determine the dates and orbital positions of the solstices via the effects of Earth's axis being tilted toward Polaris. As an option, the teacher may choose to emphasize the *reasons for seasons* or skip directly to identifying the equinox dates and positions in the Kinesthetic Circle.

Teachers then assess whether students are making the connections between orbital positions and the dates of the year by asking students to find their birthday positions. At their birthday positions, students discover that they cannot see the constellation representing their "sign" of the Zodiac in their nighttime sky. The lesson leads them to understand that their "sign" is a "Sun sign", meaning that if they look toward the Sun at noon on their birthday, the stars of their zodiacal constellation will be in the background (though not visible due to sky brightness). Students go on to explore why we see different stars at different times of year.

Finally, the students experience their kinesthetic birthdays (tilted rotation in their birthday orbital position). A few kinesthetically gifted students try to put the tilt, rotation, and orbit all together.

Earth's Orbit of the Sun [ST 9]

76. Have students stand in the Kinesthetic Circle around the "Sun". Ask: "Who has a birthday closest to today?" Identify this student and present him or her with a birthday hat (optional).

77. Ask the birthday person: "How many trips around the Sun have you made in your life?" [Pause to allow time for everyone to reflect on this question, making the connection between their age in years and the time it takes for Earth to make one trip around the Sun.]

78. Randomly ask a few other students how many trips around the Sun they have made; or if learners are of comparable age, poll them: "How many have made 10 to 11 trips?" "How many have made 11 to 12 trips?" "How many have made 12 to 13 trips around the Sun?"

79. Tell students that Earth's "trip" around the Sun is called an "orbit". Ask: "What is the shape of Earth's orbit around the Sun?" [An almost perfect circle.] Point out that this means Earth is always about the same distance from the Sun. (NOTE: Actually, Earth is a tiny bit closer to the Sun in Northern Hemispheric winter, but this does not cause the seasonal changes.)

80. Define and demonstrate the difference between "orbit" and "rotation" carefully. Ask: "How many times does Earth *rotate* around its axis during one *orbit* around the Sun?" [365 times = 365 days.] (NOTE: Ask the question in this way to connect "time" and Earth's motions.)

TEACHER TIP: As you move forward in the lesson, insist that students use the terms "orbit" and "rotation" correctly as they address questions and make their explanations.

81. Tell students they will complete one year for Earth without tilting toward Polaris. Ask: "Do you think it's a good idea to rotate *all* 365 times as you orbit?" [No, just a few times.]

82. Ask: "Which way does Earth orbit around the Sun?" Give students a hint and give them time to explore: HINT: "After the New Year, you would see Taurus in the night sky, and then later in the year you would see Leo in the night sky. Still later you would see Scorpio."

83. Poll students: "How many say Earth orbits clockwise around the Sun?" "How many say counterclockwise?" [Confirm that Earth's orbit is counterclockwise around the Sun.]

TEACHER TIP: Before having students perform the year, check to be sure that there are not obstacles they might trip over. If you are working with more than a dozen or so students, you can invite those who would like to rotate and orbit more quickly to take two steps toward the "Sun" to form an inner circle. Those who want to rotate and orbit more slowly can remain in the outer circle. For larger groups a half-year may be a better option.

84. Say: "Let's make a year happen! Start with rotation toward your "E" arm, and then begin to move in orbit around the Sun as well." [Ensure all students are rotating and orbiting in the proper sense. Enjoy their smiles. Contain students who are moving recklessly.]

85. Allow time for recovery and re-focus attention. Ask: "How long does it take Earth to orbit the Sun?" [1 year = 365 days] Define the term "Orbital Period" as the *time* it takes one body to orbit another body. Ask: "What is Earth's orbital period?" [1 year or 365 days]

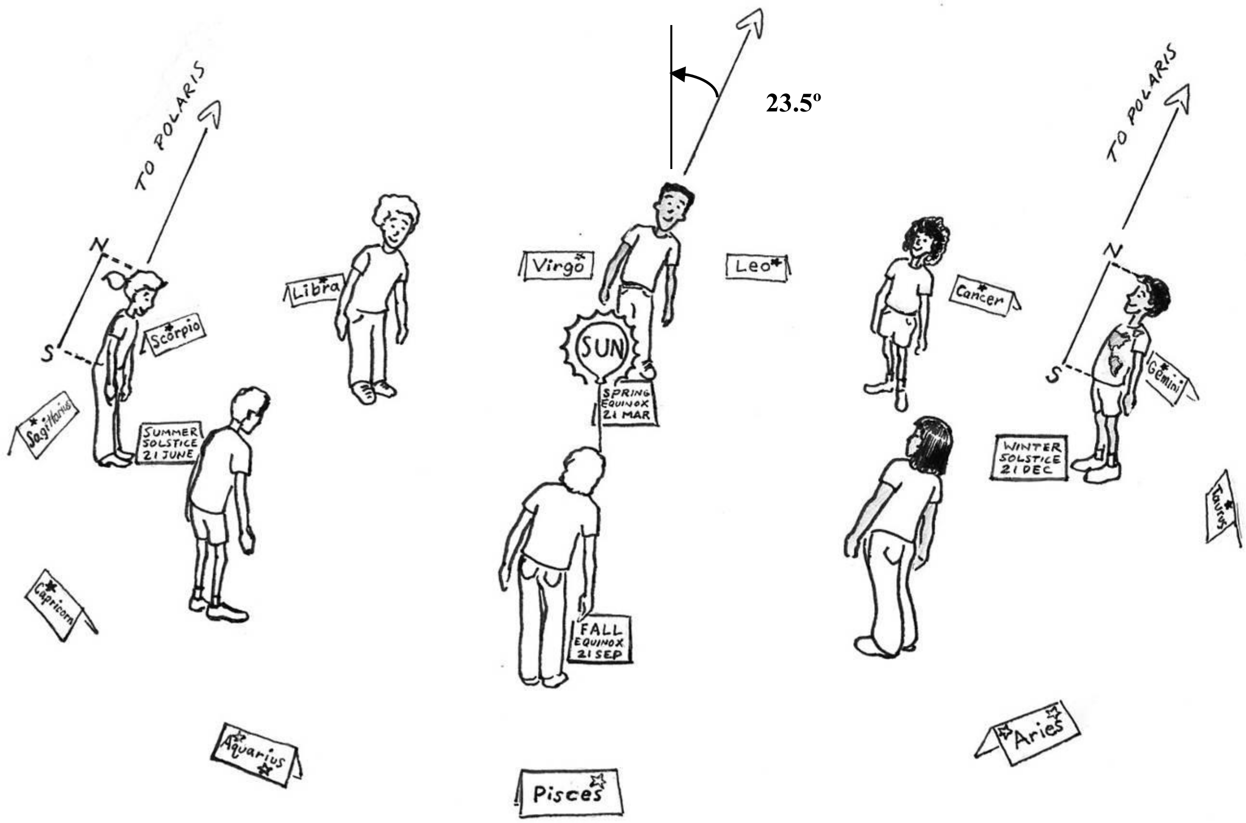
86. Give students the **"Rotation vs. Orbit" Student Worksheet [ST 9]** as homework or in-class assessment.

Adding Earth's Tilt to Identify Winter & Summer [ST 10]

Note that the "E" and "W" signs are not needed for this subsection.

87. Remind students of the tilt of Earth's rotation axis. Ask: "What is Earth's North Pole oriented toward?" [Polaris, the North Star.] "How much is the axis tilted from the vertical?" [23.5°]

88. Have all students face the Sun (midday-on-their-meridian). Have everyone tilt their bodies at the waist about 23.5° in the direction you previously chose for Polaris. Ask students to look around the circle: "Is everyone tilted toward Polaris?" [They should be as shown below.]



89. Ask: "So everyone is tilted toward Polaris, but is everyone *leaning* the same in relation to the Sun?" Follow up with: "Who has their upper body (Northern Hemisphere) leaning most directly toward the Sun?" [Identify student with forward bend directly toward the Sun?] "Who has their upper body *leaning* most away from the Sun?" [Identify the student on the opposite side of the circle who is back bending away from the Sun.]

TEACHER TIP: Emphasize this very powerful kinesthetic and visual learning moment where students can see how Earth's tilt toward Polaris can remain the same while the orientation of the hemispheres toward or away from the Sun can be different depending where Earth is in its orbit around the Sun. Many students wrongly believe that the tilt toward Polaris is what changes to cause the seasons. **It is <u>very</u> important to use "tilt" <u>only</u> to describe the constant tilt toward Polaris. Learn to speak of different hemispheres as *leaning* or *bending* toward or away from the Sun. The hemispheres' orientation is what changes, NOT the tilt toward Polaris.**

90. Ask: "What time of year is it when Earth is in each of these positions in its orbit about the Sun?" [Guide students to learn or remember that the student *bending* toward the Sun marks the first day of summer (summer solstice in the Northern Hemisphere), and the student *leaning* away from the Sun marks the first day of winter (winter solstice in the Northern Hemisphere. *Emphasize that both students are still tilted toward Polaris even though their orientation relative to the Sun is different depending on their orbital position.]*

91. Restore students to vertical and ask them for the dates of the first days of summer and winter. [21 June for summer solstice – the day with the most daylight hours; and 21 December for winter solstice – the day with the least daylight hours.]

92. Place the "Winter Solstice, 21 December" sign and "Summer Solstice, 21 June" signs on the floor in front of the appropriate students.

TEACHER TIP: Do not hang seasons signs around students' necks. Field testing proved that this lured students toward the incorrect idea that the orbital position for the summer or winter solstice moved in orbit around the Sun rather than being in a fixed place relative to the Sun.

93. Find the student who has their birthday closest to the "*Winter* Solstice". Have that person be "Mr./Ms. Winter" and stand by the "Winter Solstice" sign.

94. Find the student who has their birthday closest to the "*Summer* Solstice" and ask that person to be "Mr./Ms. Summer" and stand by the "Summer Solstice" sign.

95. While standing on the "summer" side of the circle, use an inflatable Earth or globe to show students that when the northern hemisphere is leaning toward the Sun and having summer the southern hemisphere is leaning away and having winter.

96. Walk to the "winter" side of the circle to make a similar demonstration/explanation.

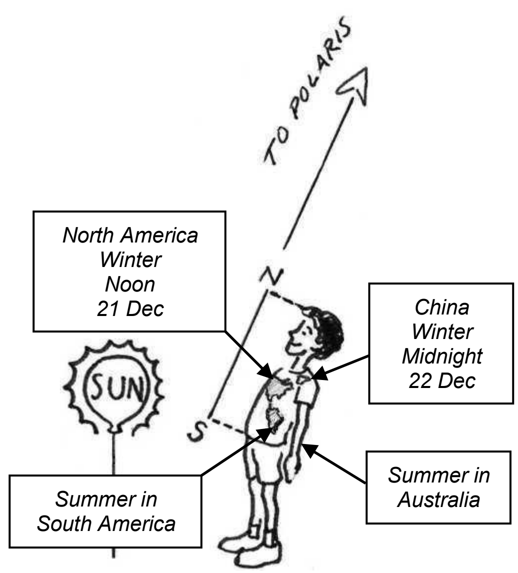
97. Have the "Winter Solstice" student serve as a demonstration model. The student should be facing the Sun (noon at their meridian). Ask a series of questions while referring to the pertinent body geography:

"What is the time at his/her meridian?" [Noon]
"What is the season in North America?" [Winter]
"What is the date in North America?" [21 December]

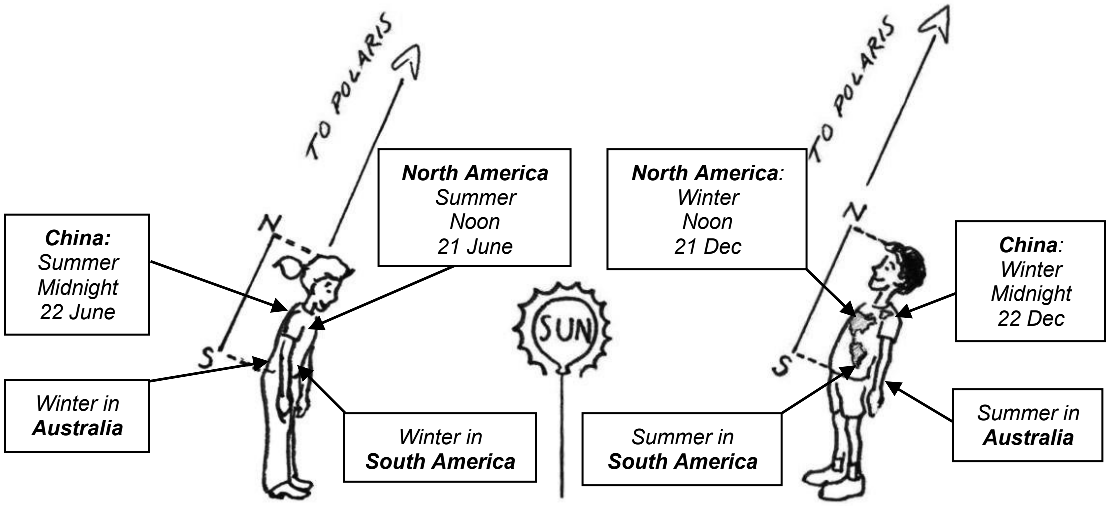
"What is the season in South America?" [Summer]
"What is the date in South America?" [21 December]

"What is the time in China?" [Midnight]
"What is the date in China?" [22 December]
"What is the season in China?" [Winter – rotate 12 hrs to prove it.]

BONUS: "What is the season in Australia?" [Summer]



TEACHER TIP: You may want to have the "Summer Solstice" student serve as a similar demonstration model. You can also have the summer or winter student turn to midnight (facing away from the Sun) and then pose the same questions. The most important point is that a season occurs in the whole northern or southern hemisphere at once, regardless of the time of day.



TEACHER TIP: The next six steps are **extremely important** for confronting the common misconception of distance to the Sun being the cause for Earth's seasons. Even though students may say that Earth's tilt causes the seasons, the *Sky Time* set-up can lead them to reason that the Northern Hemisphere is closer to the Sun in the summer and farther from the Sun in the winter.

98. Ask the Summer Solstice student to resume his/her tilt toward Polaris. Ask: "Is the Northern Hemisphere (from their chest up) of this student closer to the Sun than their Southern Hemisphere (their belly)?" [Yes, but this is **NOT** the correct scale!]

99. Remind students of the scale activity. Ask: "If Earth is the tip of a pen 50 feet away from the grapefruit-sized Sun, is tilting that pen tip going to make one part of it significantly closer to the Sun than another compared to the overall Earth-Sun distance?" [No]

100. Set the inquiry: "So what is it about the tilt that makes it colder in the hemisphere that is leaning away from the Sun and warmer in the hemisphere that is leaning toward the Sun?"

101. Have *all* students lean **away** from the Sun as if they were in winter for the northern hemisphere. [All do back bends away from the Sun.] Ask: "Do you have to look higher or lower in your "sky" to see the Sun?" [Lower]

102. Explain: If the Sun is lower in the sky, it spends less time above the horizon and we have fewer daylight hours. Ask: "Have you noticed that we have fewer daylight hours in the winter compared to summer?" [Most students have observed this.] Explain: Fewer daylight hours means the Sun has less time to warm Earth. So when a hemisphere is leaning away from the Sun we have the cooler temperatures of winter.

103. Assign **"The Dating Game" (ST 10)** as homework or in-class assessment.

Insights on the Reasons for Seasons [Optional Emphasis: ST 11 – ST 15]

This subsection supports the teacher who wants to put greater emphasis on the *reasons for seasons*. If this is not the case, it is possible to skip directly to step 128 without interrupting the flow of the lesson. Note that the "E" and "W" signs are not needed for this subsection.

104. Ask: "What makes winter different from summer?" [Lead students to say the basics, like: "It's colder in winter and warmer in summer." "The 'days' are longer in summer and shorter in winter." They will also add things about their recreational activities, holidays, etc.]

105. Set the inquiry: "Why is it colder in winter and warmer in summer?" "How can people in the southern hemisphere like Chile, Argentina, and Australia (point to these countries on a globe, if available) have opposite seasons to those in the northern hemisphere like the United States, Canada, and China?" Have students take 5 minutes to write down and/or draw pictures to explain their current reasoning. [Collect student papers and note their progress.]

TEACHER TIP: Making the thinking of *all* students visible will help you learn the effect the *Sky Time* lesson has had up to this point. Do not be surprised or discouraged if many students still do not understand the reasons for seasons. It is a difficult concept that takes time to learn. Some may already have some kinesthetic insight but are not yet ready to express it verbally.

106. Return to the *Sky Time* set-up and arrange students in the Kinesthetic Circle. Re-emphasize that the shape of Earth's orbit around the Sun is almost a perfect circle and help students make adjustments so that all are the same distance from the Sun. Emphasize that Earth's circular orbit around the Sun means that Earth's seasons **cannot be due** to changes in the distance from the Sun.

107. Have students tilt toward Polaris and place the Summer and Winter Solstice signs. [Summer sign at the feet of the student whose upper body is most directly leaning toward the Sun. Winter sign at the feet of the student whose upper body is most directly leaning away from the Sun.]

108. Ask: "Are these signs in the right place?" [Call for a show of hands for "yes" or "no" responses. Probe student thinking until all agree that the signs are placed correctly.]

109. Go to the student at Winter Solstice student and have him/her resume a proper tilt toward Polaris while in the noontime position (a back bend). Ask: Why is this winter in the Northern Hemisphere?" Probe the common misconception: "Is it because the Northern Hemisphere is farther away from the Sun?" [Ask for a show of hands: "yes" or "no" response.]

110. If there remain "yes" responses, restore the "winter" student to vertical and take time to recall (or even re-do) the scale model with the Sun the size of a large grapefruit and Earth the size of a pen tip 50 feet away. Tilt the pen tip (or tell students to imagine tilting the pen tip) 23.5º from the vertical, and ask whether any part of the pen is significantly closer to the Sun compared to the overall distance between the Sun and Earth. [Work on this until students agree that Earth's seasons **cannot be due** to changes in the distance from the Sun.]

111. Lead into the inquiry again: "So if Earth's seasons have nothing to do with distance from the Sun, what *is* it about this *tilt* that causes it to be colder in winter and warmer in summer?"

112. Have the student at Winter Solstice resume his/her proper tilt toward Polaris while in the noontime position (a back bend facing the Sun). Ask: "When the northern hemisphere (upper body) is leaning away from the Sun, do you have to look higher or lower to see the noontime Sun?" [Lower]

113. Restore the "winter" student to vertical and ask a sequence of questions that lead all students through a chain of logic regarding why leaning away causes the coldness of winter:

"So if our hemisphere is leaning away, the noontime Sun appears to be lower in the sky."
"If the Sun appears lower at noon will it spend *more* or *less* time in the sky during the day?" [Less]
"If the Sun spends less time in the sky will we have *more* or *fewer* daylight hours?" [Fewer]
"If we have fewer daylight hours, will there be *more* or *less* time to heat Earth's surface?" [Less]
"So will the temperature be warmer or colder? [Colder]

114. Now go to the Summer Solstice student who resumes his/her proper tilt toward Polaris while in the noontime position (a forward bend facing the Sun). Ask: Why is this summer in the Northern Hemisphere?" Follow up with: "When this hemisphere is leaning toward the Sun, does the Sun appear higher or lower in the sky?" [Higher. Students can sense the need to roll their eyes upward as they bend forward.]

TEACHER TIP: It is sometimes more difficult for students to perceive the noontime Sun being higher in summer. If so, it may be helpful to have them hold their right hand at the base of their chin (palm down with fingers together and pointing to the left) as they bend forward and backward. This allows them to notice how the Sun's position appears to change relative to the top of their hand. When they bend backward as in winter, the Sun appears closer to the top of their hand = closer to the southern horizon = lower in the sky. When they bend forward as in summer, the Sun appears farther up from the top of their hand = farther up from the southern horizon = higher in the sky.

115. Restore the "summer" student to vertical and ask a sequence of questions that lead all students through a chain of logic regarding why leaning toward the Sun causes the warmth of summer:

"So if our hemisphere is leaning toward the Sun, it appears to be higher in the sky."
"If the Sun appears higher at noon, will it spend *more* or *less* time in the sky during the day?" [More]
"If the Sun spends more time in the sky will we have *more* or *fewer* daylight hours?" [More]
"If we have more daylight hours, will there be *more* or *less* time to heat Earth's surface?" [More]
"So will the temperature be warmer or colder? [Warmer]

116. Assign **"Kinesthetic Seasons" Student Worksheet" (ST 11)** as homework or in-class assessment.

117. Ask: "What times of any day are *coolest*? Are the times near sunrise and sunset when the Sun is lower in the sky cooler, or are the times near noon when the Sun is highest in the sky cooler?" Show of hands for their responses. [Times near sunset and sunrise are cooler.]

118. Explain that when the Sun is higher in the sky, the Sun's rays shine down on us more directly and we feel a greater intensity of sunlight. On the other hand, when the Sun is lower in the sky, the Sun's rays come in at a lower angle and are spread out over a larger area so that we feel less intensity of sunlight.

119. Explain: In winter, the Sun appears to follow an arc that is very low in the sky during daylight hours. This means that the intensity of sunlight is much less in winter compared to summer when the Sun follows an arc that is much higher in the sky.

TEACHER TIP: For the flashlight demonstrations described below it will be necessary to dim the lights. If this is not easy to do in the learning environment you have chosen for the *Sky Time* lesson, you may skip steps 120-124 and do them in a more suitable place at a later time.

120. Gather students around more closely and use a flashlight to demonstrate the effect of the Sun's rays coming in at higher or lower angles. With the lights dim, ask students to compare the patch of light resulting from shining a flashlight on the floor from almost directly overhead to the patch of light that results from shining the flashlight from lower angles. [Guide students to notice that at lower angles (like the Sun being lower in the sky), the light is dispersed over a greater area and so it is less intense than the more concentrated patch of light resulting from higher angles of incidence (like the Sun being higher in the sky).]

121. Keeping the lights dim, hand the flashlight to one of the students and ask him/her to stand next to the symbolic Sun at the center of the circle.

122. Ask students to guide you to place an inflatable Earth in the proper tilt and orbital position for the W*inter* Solstice in the northern hemisphere. [Same as for the Winter Solstice student, except closer to the light source at the center.] Arrange students so they can all easily see the light shining on the globe.

TEACHER TIP: For a large class it may not be practical for all students to see the light on the globe. If not, then invite students either to try this demo at home or to bring in flashlights and spheres. A flashlight and globe-sized sphere for every 6-8 students is adequate for all to see.

123. Tell the "flashlight" student to shine the light toward the Northern hemisphere for several seconds, then toward the Southern Hemisphere for several seconds. Ask: "What do you notice?" "What is different about the way the light plays on the two hemispheres?" [Guide students to see how the light patch shining on the hemisphere leaning toward the light has a greater intensity, and the light patch on the hemisphere leaning away is more spread out.]

124. Explain that more intense sunlight in the Southern Hemisphere means more heating of Earth's surface and warmer temperatures of summer. Less intense sunlight in the Northern Hemisphere means less heating of Earth's surface and the colder temperatures of winter.

125. Restore the lights and introduce a rhyming jingle that serves as a reminder for why it is cooler in winter and warmer in summer:

Length of days…
Angle of rays...
Nothing to do with how far aways (sic)!

126. Have younger students recite the jingle (8^{th} grade or less). [Older students may regard this as too "cute-sy" to recite, but nonetheless they find it a helpful mnemonic.]

127. Assign **"Reasons for Seasons Concept Map" Activity" (ST 12 – ST 13)** and/or **"Reasons for Seasons" Fill-in-the-Blank Activity" (ST 14 – ST 15)** as homework or in-class assessments. Lesson Extensions 1 and 2 may also be used to enhance understanding of how different places on Earth experience seasonal change.

Finding the Equinoxes and Everyone's Birthday

Form the Kinesthetic Circle with Winter and Summer Solstice signs already set. The Zodiac ring should be in place. "E" and "W" signs are again needed in this subsection.

128. Have students resume the appropriate tilt toward Polaris. Ask: "Are there any students in the circle who are not leaning either toward or away from the Sun?" [Yes. Guide students to notice the students in side bends on both sides of the circle, half-way between the winter and summer solstice positions.]

129. Ask: "What are these new positions called when Earth neither leans toward nor away from the Sun?" [Guide students toward the term "equinox", meaning "equal night".]

130. Explain: The Summer Solstice has more daylight hours, the Winter Solstice less daylight hours, and the Equinoxes have equal amounts of daylight and nighttime hours.]

131. Ask students for the dates of the first days of spring and fall. [The spring equinox is around 21 March, and the Fall Equinox is around 21 September, plus or minus a day or two.]

132. Give students a minute or so to discuss with neighbors and make a prediction (without saying it out loud) about where to place the spring and fall equinoxes in orbit around the Sun.

133. Give the Equinox signs ("Spring Equinox/21 March" and "Fall Equinox/21 September") to the students who have birthdays closest to these dates. Ask each of them to go stand where they think their equinox should be located in orbit around the Sun.

134. Once both students have committed to a position, ask: "Are these students in the correct positions?" [Show of hands: "yes" or "no" responses.] Ask each of the two Equinox students in turn to explain why they chose to stand where they did.

135. Lead students to resolve any discrepancies by drawing their attention to which way Earth orbits the Sun and to the order of the seasons in time: Winter, Spring, Summer, and Fall.

136. Tell all students: "Go to your birthday." [This helps confirm that students are making the connection between a date and the position of Earth in its orbit around the Sun. It also gives them an interpersonal opportunity to share their birth dates with others.]

137. Check results by asking each student to report out the date of their birthday. Make any needed adjustments by drawing attention to the dates of the solstices and equinoxes and the direction of Earth's orbit around the Sun.

<u>What Does it Mean to be a "Leo"? – Different Stars for Different Seasons [ST 16 – ST 18]</u>

Students should be in their <u>birthday positions at noon</u> around the Kinesthetic Circle with "E" and "W" signs. The Zodiac ring must be in place.

138. Tell students to rotate to midnight. Ask: "Is the constellation of the Zodiac corresponding to your astrological[1] sign visible in your night sky?" [No – and this can be puzzling to those who tried to find their birthdays next to their sign of the Zodiac.]

139. Have students rotate to noon and point to their sign of the Zodiac. [Everyone points across the circle to the opposite side of the Sun.] Ask: "So, is the Zodiac set-up backwards?" "Why is everyone pointing across the circle?" [Let students puzzle for a moment.]

140. Explain: Your sign of the Zodiac is your "*Sun* sign", meaning that your constellation is in the background when you look in the direction of the Sun on your birthday. If the Sun's light were blocked you would be able to see it. If you are a Leo, we say, "the Sun is *in* Leo."

141. Ask: "If we say the 'Sun is in Leo', does that mean the Sun is anywhere near the stars of that constellation?" [No. Remind students of the scale model with grapefruits representing the Sun and nearest star on the east and west coasts of the US.]

142. Set a new inquiry: "Do people on the night side of Earth see different stars in the night sky at different times of year?" Follow up with: "Do we see the same stars in summer that we see in winter?" Have students near the Summer Solstice rotate to midnight and report the constellations they see. Have students near the Winter Solstice rotate to midnight and report the constellations they see.

143. Have all students turn to midnight. Have them note the names of two constellations they can see. Now have them stay at midnight and move ¼ of an orbit [3 months – the Equinox and Solstice students can be the guides for this amount of orbit.]. Have students again note the names of two constellations they can see. Ask: "Are you seeing different stars at this new time of year?" Shift again, if needed to make the point.

144. Ask a few students to explain why we see different stars at different times of year. [Because at different times of year, the night side of Earth faces out in different directions in space and so we see different stars.] [NOTE: If the constellations of the Zodiac are unavailable, use local objects (e.g., trees, signs, doors) to represent constellations.]

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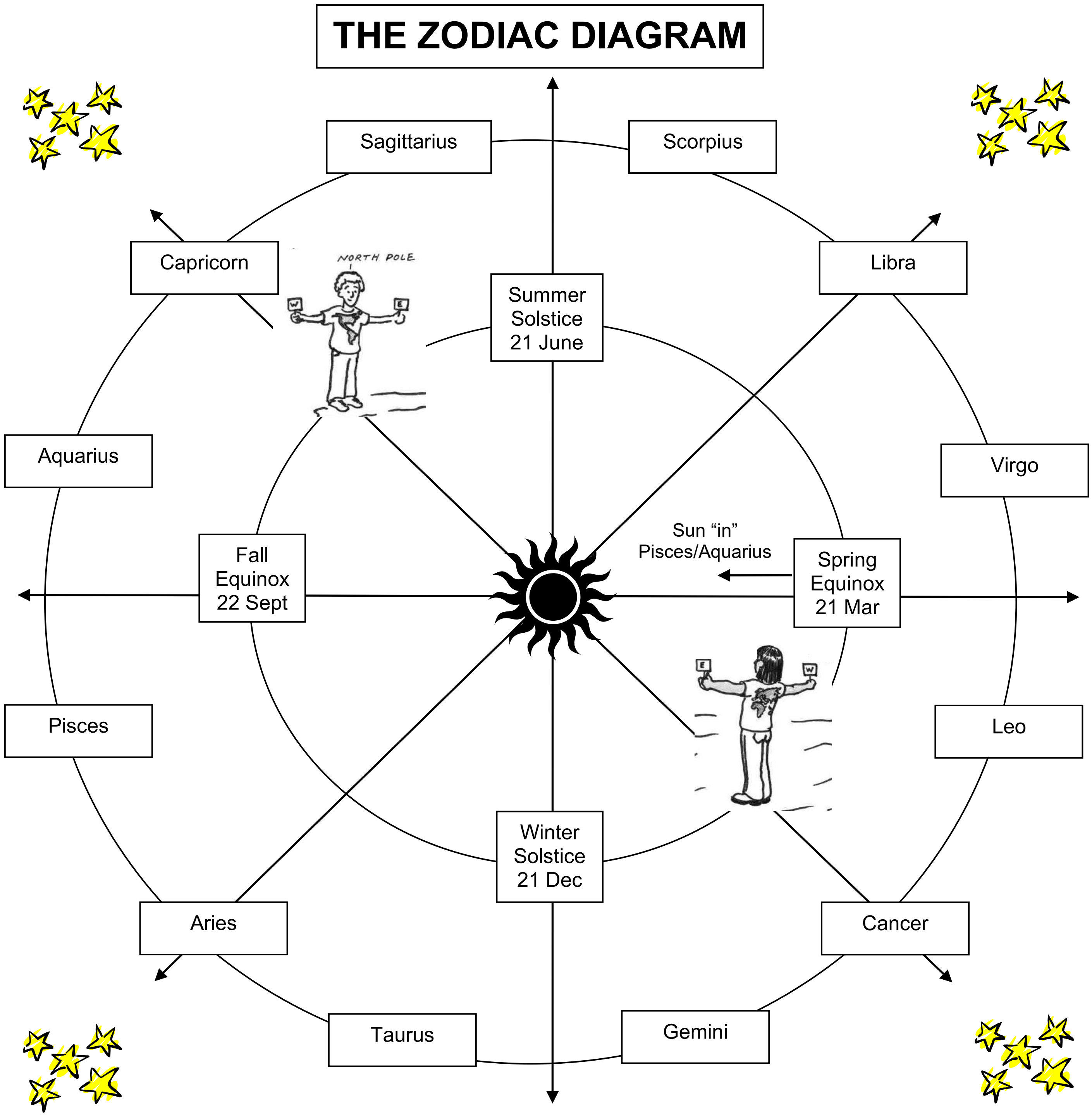
[1] Although astrology is not considered proper science, it has done a lot to popularize the names of the zodiacal constellations – patterns of stars that mark the path of the Sun in the sky as the seasons progress (the ecliptic).

145. Assign **"Your Birthday Stars" Student Worksheet (ST 16 – ST 17)** and/or **"Different Stars for Different Seasons" Fill-in-a-Poem (ST 18)** as homework or in-class assessments. "Birthday Stars" makes use of the Zodiac Diagram below. (See also Lesson Extension 3.)

TEACHER TIP: When astrological signs were first defined, the Sun was "in" Aries at the Spring Equinox. Note from the diagram that the Sun is now between Pisces and Aquarius. This is due to the "wobble" of Earth's rotation axis over thousands of years (precession). It means that the zodiac sign on your birthday no longer matches up with your sign as originally defined.



Kinesthetic Birthdays: Tilt, Rotation and Orbit

Students should be in their birthday positions at noon around the Kinesthetic Circle with "E" and "W" signs. The Zodiac ring should be in place.

146. Have students start with arms outstretched and the proper tilt toward Polaris. Invite them to "have their kinesthetic birthday". [Students complete one rotation while keeping their axis tilted towards Polaris.] Assist students who do not rotate toward the east and/or who do not maintain the orientation of their "North Poles" toward Polaris. For good humor, you may hum or sing "Happy Birthday" as students perform their tilted rotations.

147. If needed, re-demonstrate the tilted kinesthetic day and have students try their birthdays again.

148. Ask: "What is Earth's rotational period?" [24 hours or 1 day]

149. To make a meaningful demonstration of how the seasons change, have the students at the solstice and equinox positions take one step inside the Kinesthetic Circle (be sure they keep the seasons signs out in front of them). Have these "seasons" students at noon with "E" and "W" signs.

150. Have the four students go to sunset while maintaining their tilt toward Polaris. Make any needed adjustments. Draw attention to the fact that even though the time of day has changed, their tilt is still toward Polaris and their northern hemisphere is still oriented the same way relative to the Sun as it was at noon time.

151. Repeat the previous step for midnight and sunrise. Return the four "seasons" students to noon and restore them to vertical.

TEACHER TIP: If you are emphasizing the *reasons for seasons*, you may wish to use this rotation in stages at all four times of year to call attention to how the Sun is rising and setting above or below their outstretched "E" and "W" arms in summer and winter. The Sun rises and sets north of east & west in summer, and south of east & west in winter. It is also possible to use the noon and midnight positions to address why the constellations of the Zodiac appear lower in the night sky in summer and higher in the night sky in winter.

152. Choose another demo student who is adept at the tilted rotation. Start the demo student at the Fall Equinox position, at noon, and in the appropriate tilt toward Polaris (side bending to the right). Have the four seasons students assume an appropriate tilt toward Polaris. Have the demo student rotate to sunset while maintaining an appropriate tilt toward Polaris [now back bending – compare to the Winter Solstice student at noon].

153. Have the demo student rotate to midnight [now side bending to the left – compare to the Spring Equinox student at noon]. Have him/her rotate to sunrise [now forward bending – compare to the Summer Solstice student at noon].

154. Explain: No matter what time of day, the orientation of the northern hemisphere remains the same – toward Polaris. At this equinox position in Earth's orbit, no hemisphere is leaning toward or away from the Sun at any time of the day.

155. Starting at sunrise at the Fall Equinox (in a forward bend toward Polaris), have the demo student orbit in the proper sense (without rotation) from the Fall to the Winter position *while maintaining his/her tilt toward Polaris*. [At the Winter Solstice, the student is facing away from the Sun at midnight, and is tilted so that the upper back is leaning away from the Sun.]

156. Ask: "Has the tilt toward Polaris changed from the Fall position to here?" [No] "Is the Northern Hemisphere oriented differently relative to the Sun compared to the fall position?" [Yes.] "Is there a hemisphere leaning away from the Sun?" [Yes, the northern hemisphere.] "So what is the season in the Northern Hemisphere now?" [Winter]

157. Confirm the winter orientation by having the demo student rotate from midnight to noon while maintaining his/her tilt toward Polaris. [The student should have converted from a forward bend at midnight to a back bend at noon that matches up with the student already in the position of winter solstice.]

158. Explain: The orientation toward the Sun changed from Fall to Winter, NOT because the tilt toward Polaris changed, but because the tilt stayed the same while Earth moved in orbit around the Sun. The combination of constant tilt and orbital motion caused the change of season from Fall to Winter.

TEACHER TIP: A common misconception is that Earth has seasons because Earth's tilt "changes" as Earth moves in orbit around the Sun. This may cause students to try to "wobble" or change the tilt of their axis as they move around the circle. This section is stressing that the orientation of Earth's axis changes *relative to the Sun* because of their motion in orbit around it, not because of any wobbling or change in the direction Earth's axis is pointing in space. Of course, Earth's axis *does* wobble. It is called precession, but it takes 26,000 years for it to wobble once around. This wobble is negligible over a year's time.

159. Have the demo student (still at the Winter position) rotate from noon to sunrise in stages, pausing at sunrise [side bend to right]. Have the demo student proceed in orbit (without rotation) from the Winter position to the Spring position *while maintaining his/her tilt toward Polaris*. [At the Spring Equinox, the demo student is in a right side bend at midnight.]

160. Ask: "Has the tilt toward Polaris changed from the Winter position to here?" [No] "Is the northern hemisphere oriented differently relative to the Sun compared to the Winter position?" [Yes] "Is there a hemisphere leaning toward or away from the Sun?" [No] "So what is the season in the Northern Hemisphere now?" [Spring]

161. Confirm the Spring orientation by having the demo student rotate from midnight to noon while maintaining his/her tilt toward Polaris. [The student should have converted from a right side bend at midnight to a left side bend at noon that matches up with the student already in the position of the Spring Equinox.]

162. Emphasize: The orientation toward the Sun changed from Winter to Spring, NOT because the tilt toward Polaris changed, but because the tilt stayed the same while Earth moved in orbit around the Sun. The combination of constant tilt and orbital motion caused the change of season from Winter to Spring.

163. Have the demo student rotate from noon to sunrise in stages, pausing at sunrise [back bend]. Have the demo student proceed in orbit (without rotation) from the spring position to the summer position *while maintaining his/her tilt toward Polaris*.

164. Ask: "Has the tilt toward Polaris changed from the spring position to here?" [No]. "Is the northern hemisphere oriented differently relative to the Sun compared to the spring position?" [Yes] "Is there a hemisphere leaning toward or away from the Sun?" [Yes, the northern hemisphere is leaning toward the Sun] "So what is the season in the Northern Hemisphere now?" [Summer]

165. Confirm the summer orientation by having the demo student rotate from midnight to noon while maintaining his/her tilt toward Polaris. [The student should have converted from a back bend at midnight to a forward bend at noon that matches up with the student already in the position of the Summer Solstice.]

166. Explain: The orientation toward the Sun changed from Spring to Summer, NOT because the tilt toward Polaris changed, but because the tilt stayed the same while Earth moved in orbit around the Sun. The combination of constant tilt and orbital motion caused the change of season from Spring to Summer.

167. Ask: "What is Earth's orbital period?" [365 days or 1 year]

168. Ask for volunteers or select 4 students at a time who want to try and put all the pieces together (tilt, rotation, and orbit) and complete a year for Earth. Review the meaning of tilt, rotation, orbit, rotational period, and orbital period. Draw them into a tighter inner circle, start them at noon in the proper tilts, and advise them to take very small steps as they rotate and orbit in the proper sense. [Keep an eye out for "wobbling" students and guide them to maintain their tilt steadily in the same direction toward Polaris.]

TEACHER TIP: Putting the tilt-rotation-orbit pieces all together can be a bit chaotic. Only the most kinesthetically gifted students will be able to do it right away. Others will have to practice. By having only a few students at a time complete this, the chaos factor is less and you can monitor to ensure students are completing the movements of Earth correctly. It is also fun for other students to cheer for their classmates who are trying to put it all together.

IId. Applying/Assessing New Knowledge about the Day and Year [ST 19 – ST 26]

The four subsections below describe activities that call on students to apply what they have learned about Earth's day, year, and seasons. Instructors can choose from among the insights and concepts they would like to emphasize using kinesthetic techniques and the *Sky Time* set up. The "China inquiry" **[ST 19]** deepens understanding about the relationship between the day and year. The "Orion" inquiry **[ST 20]** deepens understanding about what stars can be seen at different times of the day and year. The "Earth-Mars Seasons" inquiry **[ST 21]** deepens understanding about Earth's seasons by applying concepts of tilt, orbit, and rotation to the planet Mars (for which distance to the Sun DOES matter as much as the tilt in causing the seasons). At minimum, we recommend use of the cumulative post-lesson assessment **[ST 22 – ST 26]**.

Will We See the Same Stars in the US Tonight that People in China Saw Last Night? [ST 19]

Students should be at noon around the Kinesthetic Circle with "E" and "W" signs. The Zodiac ring must be in place.

169. Set the inquiry: "Do you think we will see pretty much the same stars in the US tonight that people in China saw last night?" After a few seconds, poll students with a show of hands for a "yes" or "no" response. [Usually many students respond with "no" and if queried will explain that China is on the other side of Earth so we cannot see the same stars as they do.]

> **TEACHER TIP:** This question is not confined to consideration of the US and China. The more general question is whether people on one side of Earth will see pretty much the same stars tonight that people on the other side of Earth (at the same latitude) saw last night.

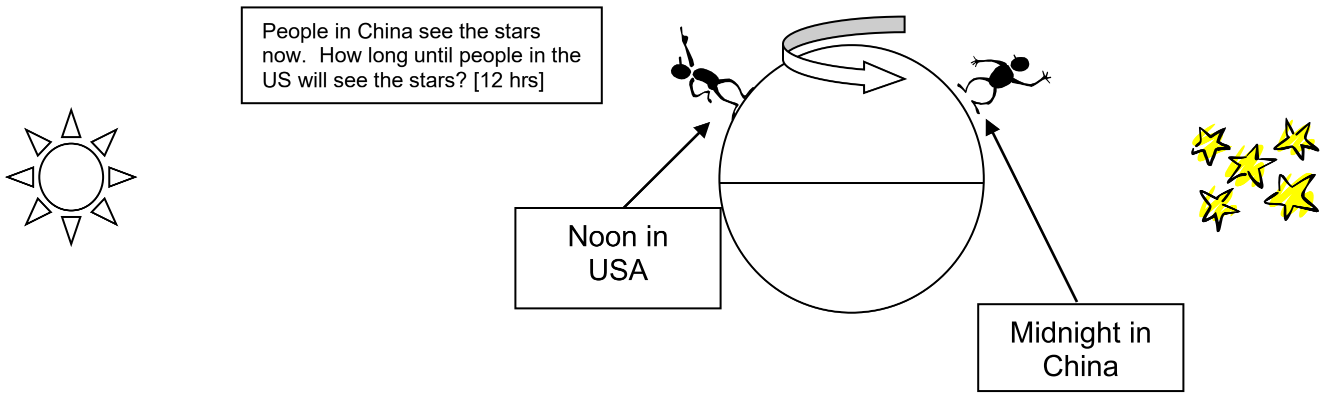
170. Ask: "How much does Earth move in its orbit of the Sun during one rotation (in one day)?" Lead their reasoning with follow-up questions: "How many degrees in a circle?" [360°] "How many days in one full orbit?" [365 days] "So about how many degrees of orbit in one day?" [About one degree per day.]

171. Have students demonstrate about how much they would move in orbit during one rotation of Earth. [Inching just a tad in a counterclockwise direction around the "Sun".]

172. Have students start at noon. Ask: "What time is it in China?" [Midnight.] "What are the people there seeing in their sky?" [The stars. Have students look over their shoulders and note at least one constellation.] "What are we seeing in the US?" [The Sun at noon.]

173. Have students rotate to midnight. Ask: "How long did it take for us to rotate to this position?" [Lead students to the answer of 12 hours = ½ day] Ask: "How much does Earth move in its orbit during this time?" [about ½º]

174. Give each student a copy of the worksheet, **"The Night Sky in China" [ST 19]**. Have students work in pairs to conduct their own investigation into the inquiry: "Do you think we will see pretty much the same stars in the US tonight that people in China saw last night?" Tell students to assume that the people in China and the US are located at the same latitude. [This is important because the stars that can be seen in the sky are different for different latitudes. See FAQ 3.]



TEACHER TIP: The worksheet **[ST 19]** also calls on student pairs to prepare and present a kinesthetic demonstration to prove their answer to the "China question". Students should have access to all the props and be free to create new ones. Students can be quite creative with their demonstrations. Some or all of their demos can be shown to the class as an assessment activity.

Who Can See Orion When? [ST 20]

Students should be in their birthday positions at noon around the Kinesthetic Circle with "E" and "W" signs. The Zodiac ring should be in place.

175. Place the **"Orion sign"** [available in the Props Section as **P 23**] as far away as practical in a direction between Gemini and Taurus. Remind students that stars rise and set and thus appear in different parts of the sky as the night progresses. Set the inquiry: "Can we see Orion every night of the year? What times of the night is Orion visible from your position?"

176. Show how students can explore this question by using the Fall Equinox student as a demonstration model. Start at noon. Ask: "Can he/she see Orion?" [No, it is setting in the west, but the Sun is up so we cannot see it.]

177. "Go to sunset." "Can he/she see Orion?" [No, looking in the wrong direction.]

178. "Go to midnight." "Can he/she see Orion?" [Yes, it's just rising in the east.]

179. "Come to sunrise." "Can he/she see Orion?" [Yes, it's on the meridian.] Return to noon and have students note that Orion is in the sky, but would fade from view at sunrise.

180. Have all students rotate with arms outstretched to explore whether they could see Orion at some time during the night at the time of year represented by their orbital position. [The student at the Winter Solstice will be able to see it from sunset to sunrise. The students at or near the Summer Solstice will not be able to see the constellation at any time of day because the Sun is between them and Orion. Every other student can see Orion for a time during their nighttime hours. The closer they are to the Winter Solstice, the more hours Orion will be visible. The closer they are to the Summer Solstice, the fewer hours Orion will be visible.]

181. Give each student a copy of the **"Who Can See Orion When?" – Student Worksheet [ST 20]**. Have students work in pairs to complete the worksheet during class time.

Comparing Mars & Earth Seasons* (reasons for seasons emphasis) [ST 21]

This Mars inquiry is excellent for those emphasizing the "reasons for seasons" because it gives students an outlet for the tenacious "distance to the Sun" misconception about Earth's seasons.

182. Give all students a copy of "**Comparing the Seasons on Earth and Mars" [ST 21].**

PLANET	Average Distance from Sun	Rotational Period	Orbital Period	Tilt of Axis
Earth	1 AU	24 hours	1 Earth year	23.5 º
Mars	1.5 AU	24.6 hours	About 2 Earth years (1.88)	25 degrees

183. Have students work in pairs to use the data table on the worksheet (shown above) and their new knowledge about Earth's day, year and seasons to address the Student Questions. Their answers can be written and/or involve kinesthetic demonstrations – ideally both.

TEACHER TIP: The written responses help translate kinesthetic learning into the verbal/linguistic realm. Possible kinesthetic demonstrations include (but are not limited to): 1) comparing the Earth year to the Mars year by demonstrating that for every two Earth orbits of the Sun, Mars makes only one orbit, and this makes Mars' seasons twice as long, and 2) demonstrating that Mars is significantly closer to the Sun in Northern Hemisphere winter compared to Northern Hemisphere summer.

184. Use the information in the **Assessment Answer Key** (which provides answers for the questions on this student worksheet) as background for leading an interactive discussion regarding the comparison between seasons on Earth and Mars.

What Have We Learned? – A Cumulative Post-Lesson Assessment Tool [ST 22 – ST 26]

"What Have You Learned?" [**ST 22 – ST 26**] is a post-lesson assessment tool designed to evaluate how student thinking and understanding have evolved as a result of the *Sky Time* lesson.

185. Select questions according to those concepts and activities you chose to emphasize. You may also wish to include opportunities for students to demonstrate their understanding in a kinesthetic manner, either as preparation for, or as part of the assessment.

186. Prepare students by reviewing the portfolio of worksheets completed during the lesson.

187. Compare the results of the post-lesson assessment to related questions in the pre-assessment questionnaire **[ST 2 – ST 4]** given at the outset of the lesson. Seek evidence of any changes in knowledge and understanding, and particularly any shifts in prior misconceptions.

188. END of the *Sky Time* lesson.

III. LESSON EXTENSIONS

1. An 8-in diameter balloon and a light source provide the tools to create a visual demonstration of the midnight sun in a simple but powerful way. Inflate a light blue balloon to represent Earth. Hold it vertically before a light source that illuminates exactly one half of it. [The line between light and dark should run right through the North Pole]. Now tip the top of the balloon toward the light source [as if at the Northern Hemispheric summer solstice] and note what happens to the light in the Polar Regions. Rotate the balloon (counterclockwise from above) and observe how the north polar region is in light all day (midnight sun) and the south polar region is in darkness all day. Tip the balloon the other way as if in northern hemispheric winter to show how the North Pole is in darkness throughout Earth's rotation. If desired, you can go on to see what happens for lesser latitudes, noting the wider band of light in the hemisphere leaning toward the Sun (more daylight hours), and the narrower band of light in the hemisphere leaning away (fewer daylight hours). (NOTE: If the balloon's color is too light or dark, the contrast between shadow and light is not adequate to gain the visual insight. It is best to test a balloon out before buying them in quantity.)

2. A Solar Motion Demonstrator (see resources section) is an excellent companion to any lesson related to seasons on Earth. This simple and inexpensive device allows each learner to explore the Sun's path in the sky at different times of year at different northern latitudes.

3. If students have and know how to use planispheres (see resources section), they can set up the Zodiac on their own and discuss more precisely what we see in the sky at different times of the night and year. Students can also explore how the rise and set times of the Sun change during the seasonal cycle. In addition, students can gain greater insight into the relationships between the ecliptic and celestial equator at different times of year.

4. Have students consider seasons on Uranus whose "tilt" from the vertical is about 98º.

5. The "Sky Time" set up can be used to explore the effects of the 26,000 year "wobble" of its rotation axis and other longer term changes in Earth's orbital characteristics.

IV. REFERENCES and RESOURCES

1. Raymo, Chet, *365 Starry Nights: An Introduction to Astronomy for Every Night of the Year*, Prentice-Hall, Inc. (1982). ISBN: 0-671-76606-6

2. Rey. H.A., *The Stars: A New Way to See Them,* Houghton Mifflin Company, Boston, MA (1980). ISBN: 0-395-24830-2

3. Bennett, Jeffrey, Megan Donahue, Nicholas Schneider, Mark Voit, *The Cosmic Perspective,* Addison Wesley Longman (2004). ISBN: 0-8053-8738-2

4. Planispheres and Solar Motion Demonstrators can be ordered from the Astronomical Society of the Pacific (ASP) online store: https://myasp.astrosociety.org/products/education

5. *A Private Universe* is a video/DVD production that illustrates the tenacity of misconceptions about the seasons and lunar phases. Twenty-one out of 23 Harvard graduates interviewed were unable to give a scientifically correct explanation for the seasons. https://www.learner.org/series/a-private-universe/

6. Sometimes, original *Astronomy To Go* Earth T-shirts are sold on eBay. https://www.ebay.com/itm/111173582461. It is also possible to make a simple paper model of north & south America for hanging around students' necks.

V. 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?

Yes, all stars 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?

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?

No. Earth is spherical, 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?

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?

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. For example, 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 (0° above 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.