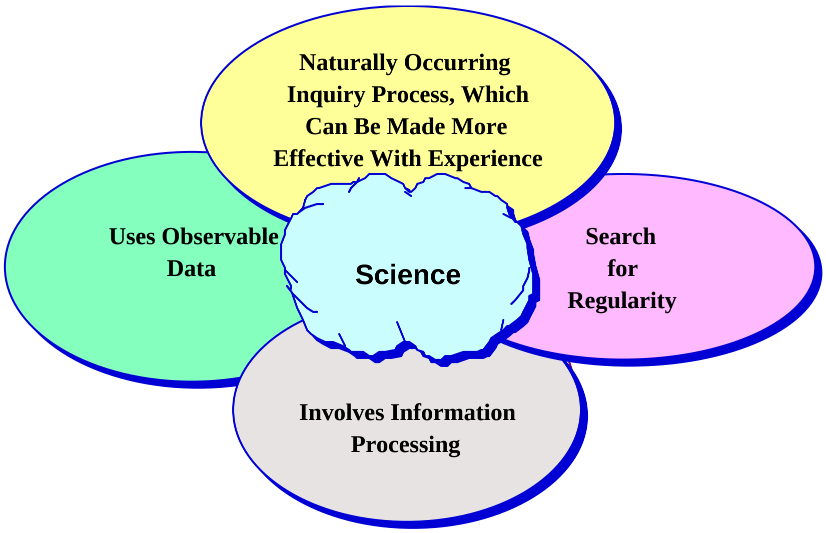
Science in the Elementary and Middle School



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Chapter 15
Earth and Space Science Starting Points

Overview

Researchers observing elementary and middle school classrooms have identified numerous areas in the earth and space sciences where students hold alternative conceptions that create a barrier to learning. How do students learn more scientific explanations for earth and space science events? How should earth and space science be taught to take advantage of a student's prior knowledge?

Starting points are presented in this chapter to demonstrate the learning cycle strategy for the earth sciences. The chapter first presents an overview of basic content needed by all students. Second, the chapter presents the basic ideas in one area in earth and space science, the earth in space, for an elementary and middle school science curriculum. Next, selected alternative conceptions in the area of earth in space are provided to demonstrate specific needs that students have. Specific instructional strategies are discussed for earth in space difficulties to illustrate general strategies for earth and space science concepts. These specific alternative conceptions are followed by a discussion of alternative conceptions in the more general earth and space science areas relating to the Earth's oceans and atmosphere, space science, geology, the solar system, stars, and the universe. Following each general earth and space science alternative conception, examples of discrepant event activities and learning cycle lesson plans are provided. These discussions provide a foundation for teachers who wish to effectively plan lessons that assist students in their learning of earth and space science concepts.

Chapter Objectives

1. Give several examples of students' alternative conceptions in earth and space science.
2. Describe a procedure for interviewing students about their prior knowledge concerning ideas in the earth and space sciences.
3. Given a common alternative conception in earth and space science, describe a discrepant event activity that confronts students with their alternative conception.
4. Given an earth and space science lesson plan, identify possible alternative conceptions students might bring to the lesson.
5. Develop one or two key questions to create a "confrontation" and a possible student investigation in the Exploration phase of an earth and space science lesson.
6. Evaluate an earth and space science lesson plan to determine whether the activities appropriately connect students' alternative conceptions to the content goals of the lesson.

What is Needed in the Area of Earth in Space?

The earth and space sciences deal with the Earth or any part of it and the Earth's space environment. The earth and space sciences include the disciplines of geology, oceanography, meteorology, and astronomy, among others. The earth and space sciences have developed rapidly during the twentieth century. They involve the application of both the physical and biological sciences in a study of Earth, the solar system, and its place in the universe. The rate of knowledge expansion in the earth and space sciences is increasing and is expected to continue to do so throughout the twenty-first century.

The key ideas in the earth and space sciences involve concepts as diverse as properties of materials, weather, the dynamic earth system, aerodynamics, space flight, the solar system, stars, and the universe (see Table 15.1). In the earth and space sciences, the Earth in space is a topic covered as a unit of study, or indirectly with other ideas in the elementary and middle school science curriculum.

Table 15.1
Examples of Key Ideas in the Earth and Space Sciences

Grade Level	Properties of Materials and Weather	Earth Systems	Aerodynamics and Space Flight	Solar System	Stars and the Universe
Primary Age (K-2)	Weather can be a solid, liquid, or gas as experienced in everyday events.	Many events in nature have a repeating pattern (e.g. weather, Sun movement).	Different objects have different flight patterns.	The Sun provides heat and light. Shadows provide information about the Sun's movement.	Stars can be distinguished by their brightness, location, and patterns.
Intermediate (Grades 3-5)	Earth's materials are solids (rocks and soil), liquids (water), and gases (the atmosphere).	Changes on the Earth can take place quickly or over long time periods (e.g. earth quakes and erosion).	The shape of objects can be used to predict their flight characteristics.	The Sun and moon are seen in repeating patterns due to the Earth's spinning on its axis.	Stars have a daily repeating movement due to the Earth's turning and yearly due to the Earth's orbit around the Sun.
Middle School Grades 6-8)	Soils have many properties that identify them including texture, color, origin, capacity to retain water, and ability to support plant growth.	Cycling of water in and out of our atmosphere plays an important role in determining climatic patterns.	Motions of objects outside of the Earth's atmosphere are related to forces of gravity and thrust produced by the mass of material being expelled by the object or hitting the	Due to the Earth's turning on an axis that is tilted to the plane of the Earth's yearly orbit around the sun, the Sun is seen to rise higher and take a longer path in the sky during	The Sun is a medium-sized star near the edge of a disk-shaped galaxy of stars that can be seen as the Milky Way in the night sky.

			object.	the summer months of the year.	

Basic concepts covered in units involving the earth in space in the national and state standards, textbooks, state curricula, and teacher-made lessons include the following.

Early childhood students (kindergarten - grade two) should have experience with and understand that:

1) Some events in nature appear once, while others have a repeating pattern. The motions of the sun, moon, and stars all have regular patterns.
2) The sun appears in different locations in the daytime sky. The location is related to the time of day and the seasons. The location of the sun can be determined by its height in the sky and its direction along the horizon.
3) Sometimes the moon is in the sky at night and sometimes it's in the sky during the day. The moon looks different every day. It gets larger and then smaller and repeats its shape change month after month. The location of the moon in the sky is different from day to day. Evidence for its location can be determined from its height in the sky and its place along the horizon.
4) There are more stars in the sky than we can count. They do not all have the same brightness and color. They are scattered throughout the sky unevenly. Stars appear only in the evening sky. Stars appear to move slowly together across the sky each night.

Elementary and middle childhood students (grades three - eight) should have experience with and understand that:

1) The **sun** is the closest star in the sky. Its motion, if carefully observed, tells us how the earth is moving. The sun's motion, from east to west, gives us evidence that the earth is rotating on its axis from west to east. From month to month, the change in altitude of the sun at noontime is visible. It is evidence for the tilt in the axis of the Earth. The tilt causes each part of the Earth to be angled closer to the sun in one part of the Earth's revolution around the sun and farther away during another part of that revolution.
2) The **moon** revolves around the earth every twenty-eight days. Because of the changing angle of the sun during the year, this revolution causes the shape of the moon to change in a regular cycle. The moon changes from a thin crescent to full and back to thin crescent again. When the moon is on the opposite side of the Earth than the sun we see a full moon. When the moon appears close to the sun in the sky, it is located between the Earth and the sun. At this place in its orbit, just a small part of the moon's surface is lit up so it appears as a crescent to an observer on Earth. The moon's revolution also causes its location to change each night and from day to day. This motion is in addition to the apparent motion caused by the earth's daily rotation.
3) **Planets** in the sky look similar to stars. Some planets are brighter than any of the stars. The different appearance of a planet and a star can be observed with a telescope or by watching them over a period of time to see if they change their positions among the other stars. Planets change their position but stars remain in the same place when compared to the location of other stars. The earth is one of nine planets in orbit about the sun. All the planets revolve in the same direction, counterclockwise, around the sun. Planets vary in size, composition, surface features, and distance from the sun. As companions to our sun, planets are the largest of many types of objects that are part of the solar system. Some

planets show evidence of geologic activity. Other objects in the solar system include natural satellites, asteroids, comets, flat rings of rock and dust particles orbiting a planet, and other solid, rock-like, nameless objects that range from miles in diameter to specks of dust.

The shape of the solar system is flat. As the planets are observed from Earth, they always appear to be located in a small band of stars encircling the Earth. An observer watching from mid-latitudes on Earth cannot see planets very far to the north or very far to the south.

4) **Stars** are suns that are so far away that even though they have motions of their own, to the naked eye, each seems to continuously remain stationary in relation to the other stars around it. Stars in the night sky are different distances from earth, but they are so far away that they all appear to be the same size. The Sun is an average star in terms of its physical characteristics. Stars have different sizes, temperatures, compositions, and life histories. The energy a star gives off is created deep in its core through nuclear reactions. It is transported over time to the star's surface where it is given off in the form of light and other types of radiation.

Patterns in the stars' locations have been given names and are known as **constellations**. In addition to the apparent nightly motion of stars due to the earth's rotation, stars appear to slowly move westward about one degree per day. This is an apparent motion due to the earth's orbital motion around the sun. This second apparent motion causes different stars to be seen in different seasons in the night sky.

5) Stars are located in very large groups called **galaxies**. The Sun's galaxy can be seen as a glowing band of light that arches across the night sky and is called the Milky Way. Its shape is flattened and encircles the earth and the sun, as evidenced by the glowing band of light. The universe contains many such galaxies as the Milky Way. Galaxies are organized into large groups separated by relatively few galaxies.

Alternative Conceptions About The Earth in Space

A specific area of earth and space science is explored below in detail to provide examples of how student experiences are used to introduce discrepant events that confront their prior knowledge. Effective lesson plans can then be constructed, creating meaningful learning for students that takes into account their when prior experiences and ideas.

The Earth and sky are experienced by all humans starting early in life. Students always compare their common sense view of where they live to the ideas presented in classroom science lessons. When a fourth-grade teacher comes to a chapter in the textbook entitled "Earth in Space" and reads the teacher's guide providing objectives and science vocabulary, concepts such as globe, planet, orbit, pole, rotation, and axis will be found. Students have already developed ideas related to each of these terms. To take advantage of a student's prior knowledge, it is necessary to first provide students with observational and other concrete experiences that relate to the idea being introduced. When these observational experiences are part of an Exploration in a learning cycle format, the teacher confronts the students with an activity that elicits what they know and believe about the idea. Listening to student responses in whole class settings and asking them to listen to peer responses and discuss each other's responses in small group settings provides students and the teacher with starting points for an effective earth and space science lesson. These starting points are students' prior knowledge. This knowledge guides student perceptions about what they have experienced in the real world and what they will learn from your lesson activities.

A Practice Activity

Typical Ideas Students Have About Earth in Space

Answer the questions below:

1. List some of the facts, concepts and generalizations in an earth in space unit that are appropriate for an early childhood student.
2. What alternative conception do you think an early childhood student in the kindergarten or first grade has about the earth in space?
3. List some of the facts, concepts and generalizations in an earth in space unit that are appropriate for a middle childhood student.
4. What alternative conceptions will an older middle childhood student have about the earth in space?
5. Label the statements in 1. and 3. above with “C” for concept and “G” for generalization. Are there any facts above? If so, put an “F” in front of the statement. When planning a lesson, the same instructional strategy cannot be used effectively for every type of content.
6. Now, look at the suggested answers below and compare your responses to them. The answers do not encompass all possible ideas, but these concepts and generalizations should be included in planning units on Earth in space. Compare the answers below with your responses and comment.

For questions 1 and 3, possible Earth in space concepts and generalizations are listed below. Others are found in the next few pages in the discussion of student alternative conceptions about Earth in space, or in state and national science education standards. Still other examples are found in the preceding section. Compare your responses to those suggested below. The “ *” indicates examples appropriate in early childhood (K-2). Other examples should be introduced in the third and later grades. A focus on use and transfer should occur in the 5th and later grades.

<u>Some Earth in space concepts are:</u>

*observing components of the sky - clouds, birds, Sun, moon, stars, etc.; *horizon; *observing shadows; *observing the motion of planes and clouds in the sky; orbit; rotation; revolution; eclipse; clarity of the sky; zenith; cardinal points of the compass; motions of stars, planets, the moon, meteors etc. in the sky.

<u>Some Earth in space generalizations include:</u>

*The closer an object is to a moving observer, the quicker it will seem to pass.

*The higher the sun is in the sky, the shorter the shadow it will cast.

* The greater the angle between the sun and the moon, the greater the amount of the moon that will be lit by the sun.

*The speed of a planet in orbit around the sun decreases the further its distance from the sun.

*The greater the tilt of the Earth’s axis, the greater the difference in seasons.

*The greater the tilt of the Earth’s axis, the larger the temperature difference between summer and winter.

For questions 2 and 4, examples of alternative conceptions are found in the pages that follow.
For question 5, see chapters 4 and 5 if you are in doubt about whether you have written a fact, concept or generalization.

A long-term effort must be made to help students modify commonly-held alternative ideas. Examples of students' alternative conceptions about the Earth in space include the following six ideas (Cohen & Kagan, 1979; Nussbaum, 1979; Sneider & Pulos, 1983; Nussbaum, 1985; Sadler, 1987; Lightman & Sadler, 1988; Baxter, 1989; Vosniadou, 1989; Phillips, 1991):

1. Student alternative conception. *Day and night are caused by the Sun going around the Earth. The Earth rotates in 24 hours.*

   Young students often believe that the Sun is moving because they have noticed the Sun's circular path around the sky. Of course, the reverse is true; the Earth moves around the Sun. Yet, when one studies the sky, it is easy to form the perception that the Sun is moving around the Earth.

   The Earth rotates on its axis once every 23 hours and 56 minutes. This rotation causes the Sun to appear in the same part of the sky once every day. However, it is only roughly in the same spot. Actually, it takes 24 hours and zero minutes for the Sun to return to the same spot where it was seen the day before. The Earth is rotating four minutes faster than this.

   More than rotation is occurring. The Earth is also revolving, moving in an orbit around the Sun. It moves about one degree a day eastward on its 360 degree path around the Sun, thus adding to the rotation angle the Earth must make to bring the Sun up to the same point in the sky. From noon to noon on consecutive days, the Earth must rotate 361^{o}. The Earth takes four minutes to rotate this extra degree. One degree of movement makes a difference when we look for the Sun, we see it in exactly the same spot it was 24 hours earlier. These two Earth motions, rotation and revolution, work together to create the appearance of the Sun moving through the sky daily on a predictable path, and suggest to us that the Sun moves around the Earth, not that the Earth moves around the Sun.
2. Student alternative conception.*The Earth is flat. The Earth is round like a pancake. The Earth is round and it is in the sky. The Earth is spherical and people live in a flat place on top.*

   One of the most common alternative conceptions for younger students involves the shape of the Earth. Students are told that the Earth is round, yet, the Earth appears flat when we stand on it. Students are asked if they believe that the flat ground they walk on, ride on, and play on actually wraps itself around to form a giant ball. Students confused by what they actually see and what they are told exists form alternative conceptions by leaving out some of what is told to them or by mixing what they know with what they have been told.

   Students form alternative conceptions because they find it difficult to give up the idea that the Earth is flat. To reconcile the concept of a flat Earth with a spherical Earth, some students create an alternative conception that the Earth is disk shaped. Others believe that there are two Earths: a round one that is a planet up in the sky and a flat one that people live on. Believing that there are two Earths allows them to keep their flat Earth idea and account for the "official" idea of a spherical earth. Somewhat older children mix their ideas with school knowledge in a complex way. They create an idea of an Earth that is spherical but has a flat place on top where they actually live. Tied up with these ideas are other barriers to learning. Since gravity pulls things down, students believe living on a flat earth means that gravity always pulls things in the same direction, down. They mix concept, for example, if they believe in a spherical Earth with a flat place on top, they construct the belief that gravity in other parts of the world pulls things off of the Earth. So, objects thrown upwards in the southern hemisphere, for example, will keep on going up.

3. Student alternative conception.*The Moon is stationary, it does not move. The Moon is located in a part of the sky that is always dark. The Moon goes around the Earth in a single day*.

The Moon is a satellite of the Earth. It revolves slowly around the Earth, taking about 28 days for one complete revolution. The Moon does not move in its orbit quickly. It moves about 12 degrees per day. This is determined by dividing 360 degrees by 28 days. The moon is in the day sky for about 14 days and in the night sky for about 14 days. The moon is visible some place in the sky about 25 of the 28 days it takes to make one revolution. The rest of the time it is too close to the Sun to be easily seen.

When viewed in the sky during a clear evening, the Moon seems to be suspended and unmoving. If one waits an hour, the Moon will have moved 15 degrees closer to the western horizon because of the Earth's rotation. The Moon will set in the west later in the night. If students look for the Moon at different times during the same day, they will notice the continued effect of the Earth's rotation on the Moon. To them, the Moon will appear to travel once around in a day because of the Earth's rotation.

The next evening, at about the same time, the Moon will appear to have shifted eastward by 12 degrees compared to its position in the sky 24 hours earlier. This motion is due to the Moon's revolution. If the evening Moon were compared to its location in the stars an hour before, one would notice a change of one-half degree. One-half degree is equal to the Moon's diameter.

4. Student alternative conception. *The Earth revolves around the Moon. Different countries on the Earth see different phases of the Moon on the same day. Phases of the Moon are caused by a shadow from the Earth.*

The Moon is about 240,000 miles from the Earth. At this distance, everyone on the side of the Earth facing the Moon will see the Moon in the same way. The **phases** of the Moon occur because at times the Moon is near the Sun, the source of light illuminating the Moon, and at other times it is behind us on the opposite side of the Earth from the Sun. A small portion of the Moon is lit up when it is near the Sun in the sky. More of it is lit up as it orbits further from the Sun, so, the phase of the moon is different. The only time it shows no dark portion, the full moon, is when the Sun and Moon are on opposite sides of the Earth. This is the only possible time when the Moon could be in the Earth's shadow. When the Moon does pass in the shadow of the Earth there is a lunar eclipse. The lunar eclipse can only occur during a full moon. The Earth's shadow is a small disk because of the great distance the moon is from the Earth. Most of the time, the Moon misses the Earth's shadow during its orbit of the Earth.

5. Student alternative conception. *The Sun is directly overhead at noon. The daylight is the same length as our local day on any part of the Earth. The amount of daylight time*

increases throughout the summer months.

For anyone above 23 1/2 degrees north latitude, Tropic of Cancer, and in every state in the USA except Hawaii, the Sun is never overhead, at the zenith, at noon or at any other time. The Sun's path during a single day begins on the eastern horizon. It climbs very high until the Sun reaches the south where it is at its highest point during the day. For people living in tropical regions south of 23 1/2 degrees north latitude (and north of 23 1/2 degrees south latitude), the sun will appear overhead at noon only twice a year. For a person living on the equator, the sun will only be at overhead at exactly noon on March 21 and September 21 each year. For people living in the United States, the sun at noon on those dates will appear at a medium angle in the southern sky (Figure 15-1).

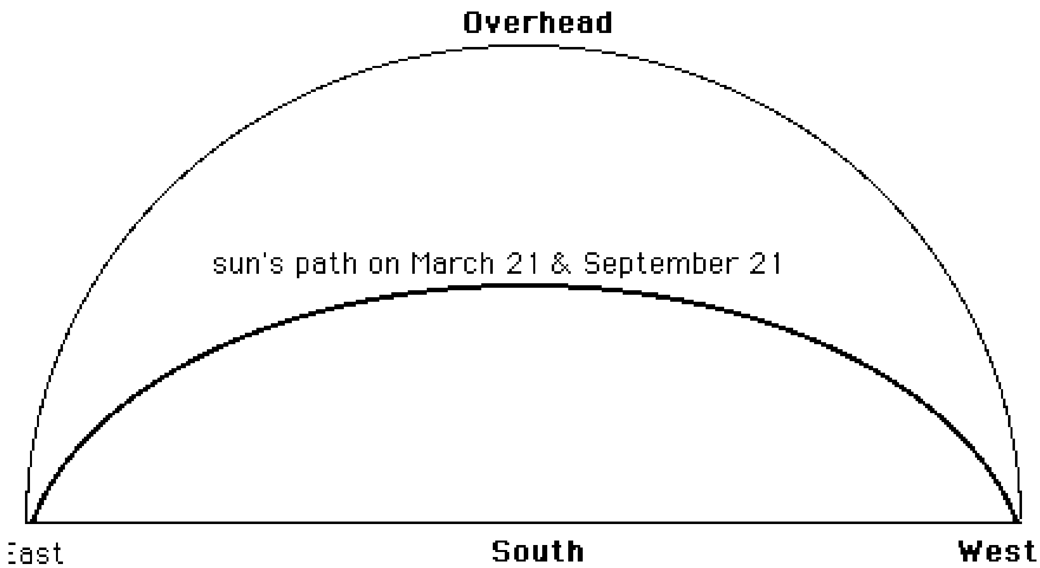

Figure 15-1: The sun as seen from locations in the United States on March 21 and September 21 each year.

The further north a person is on the Earth, the lower the angle the sun will appear in the sky at any time. Try this experiment out: Call up a friend who lives a great distance from you directly south or north. Do this near noon on an agreed-upon day. Two people viewing the sun on the same date and measuring the height of the sun at the same time, for example in Mobile, Alabama and Detroit, Michigan, will see the sun at different heights in the sky. At noon, the person in Detroit will see the sun 12 degrees lower in the sky closer to the southern horizon, than will the person in Mobile (Figure 15-2).

In the summer throughout the contiguous 48 states in the USA, the sun is between 5 and 25 degrees from the point overhead, the zenith, at its highest point during the day. The zenith is at a height of 90 degrees from the horizon. This is the same as saying that it is between 65 (90^o - 25^o) and 85 (90^o - 5^o) degrees altitude from the southern horizon. The range of degrees is given to show the height of the sun from northern and southern locations in the United States.

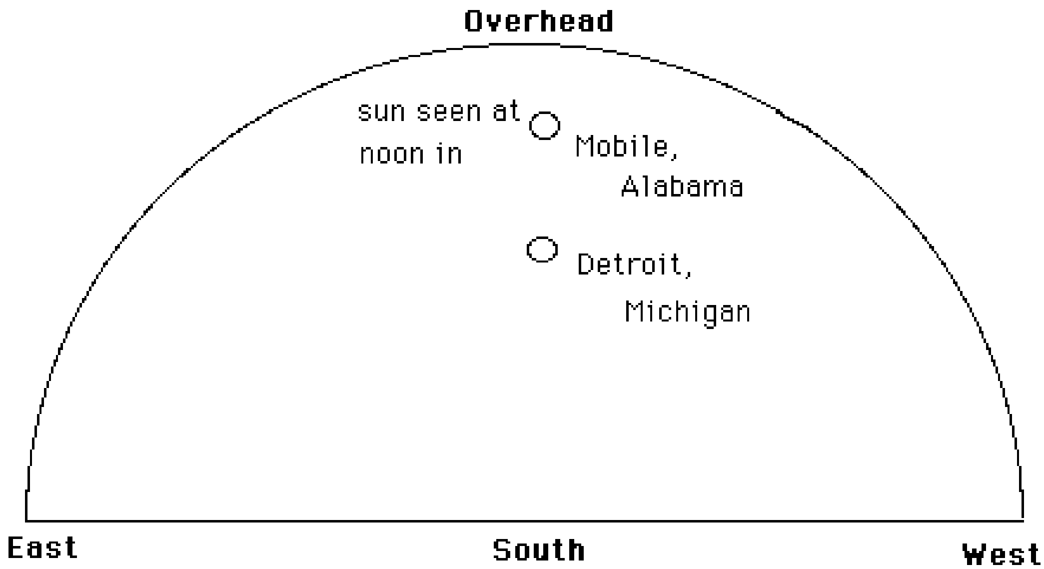

Figure 15-2: The sun seen at noon on the same day from two different locations. One location is south of the other.

In the winter, the sun's highest point is also in the south. However, it is between 57 and 72 degrees from the point overhead. The altitude of the sun at noon in the winter is between 18 and 33 degrees in the continental United States.

Every day following June 21, the sun will appear to be lower in the sky when you look at while standing in the same location. So, the sun's height and total path length in the sky above the horizon become smaller during the summer months of July and August. They do not increase during the summer months (Figure 15-3).

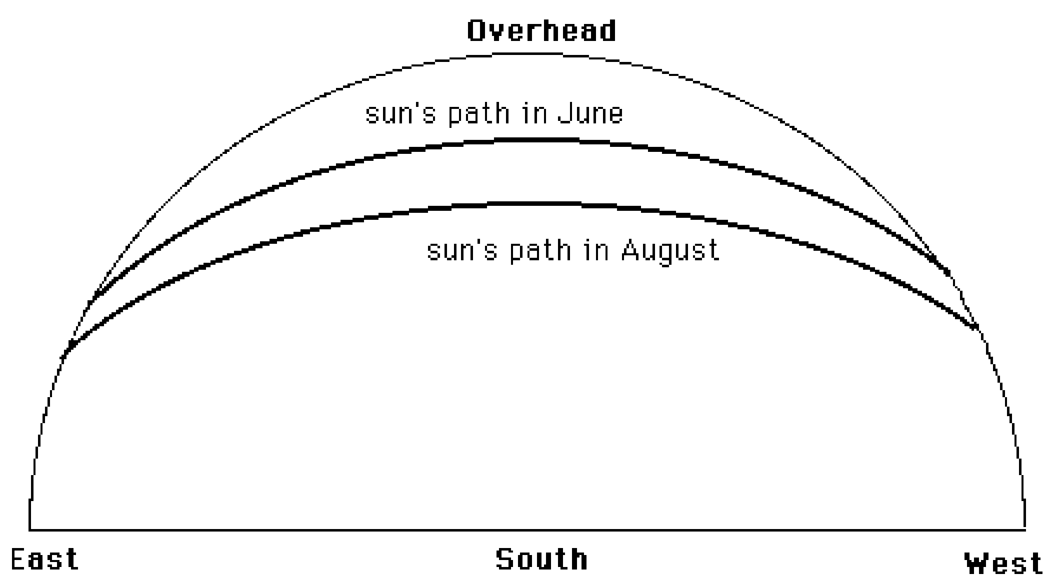

Figure 15-3: The sun's path in two different summer months seen from the same location.

Because of the low angle of the sun in the winter as compared to the Sun in the summer, the total path of the Sun is much shorter. The shorter the time that the sun can be seen means that the length of the day is shorter and that the night is proportionately longer. The sun is lowest in the sky on December 21 in the northern hemisphere. That is the shortest day in the year everywhere in the northern hemisphere. The sun is highest in the sky in the northern hemisphere on June 21, so it is the longest day of the year. Between December 21 and June 21, the sun is a little higher in the sky at noon every day. The rising and setting points of the sun move slightly northward each day. By June 21, the sun rises in the northeast, moves to a point close to the zenith in the sky, and sets in the northwest. The sun is in the sky much longer than 12 hours on this date. The sun's path is longest on this date (Figure 15-4). From June 21 to December 21, the process reverses. The sun gets lower every day, the path of the sun gets shorter, and there are fewer daylight hours (Figure 15-4). For all of the summer, after June 21 on, the days are getting shorter.

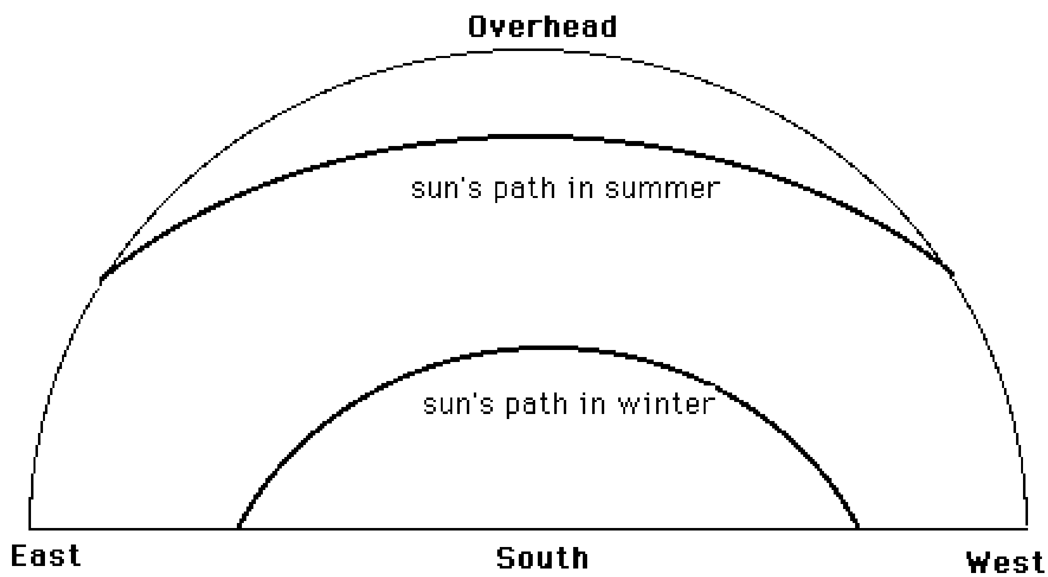

Figure 15-4: The sun's path during different months of the year.

6. Student alternative conception. *The Sun revolves around the Earth. The Earth is in the center of the solar system. The seasons are caused because the Earth is closer to the Sun in summer.* The Earth and all other components of the solar system revolve around the Sun. More than 99% of the total mass of the solar system is in the Sun. Its strong gravitational pull causes the orbits of the planets to be centered on the Sun. When seen from the top of the solar system, the remaining mass of the solar system, less than 1%, is moving in the same counterclockwise direction. This remaining mass is mostly made up of the nine planets of the solar system. This mass, including the Earth, is not spread evenly around the Sun, but is strung out in a flat disk-shaped mass centered on the Sun. There is almost no material above or below the Sun.

The Earth is in orbit around the Sun in a nearly perfect circle. There is about a 3% variation between the closest and furthest points from the Sun. The Earth is closest to the Sun in January and furthest from it in July. This is enough to cause only minor changes in the Earth's weather, warming the northern hemisphere slightly in the winter.

It is not enough to create seasons on the Earth. Evidence for this distance can be found by counting the days on a calendar between March 21 and September 21 and comparing this number to the days between September 21 and March 21. The first time period is longer because the Earth is further from the Sun and is moving slower in that half of its orbit.

At the same time as the Earth is revolving about the Sun, the Earth is rotating but its axis is not perpendicular to its orbit. Its axis is tilted 23 1/2 degrees from its orbit. The rotating Earth is spinning in such a way that like a gyroscope, its axis is always pointing in the same direction towards the same stars in space. As the Earth revolves around the Sun, its northern axis is at an angle of 23 1/2 degrees, pointing toward the Sun for half of its orbit. This occurs during the period from March 21 through September 21. As seen by a person in the Earth's northern hemisphere, the Sun will appear high in the sky (Figure 15- 5). From September 21 through March 21, the Earth is in the other half of its orbit. Its northern axis is at an angle of 23 1/2 degrees, pointing away from the Sun. When this occurs, the Sun is directly over some portion of the southern half of the Earth. As seen by a person in the northern hemisphere, the Sun will appear low in the sky (Figure 15-5). Because the Sun is higher in the northern hemisphere in the summer, it shines for more hours and more heat energy shines on every square meter of the northern hemisphere.

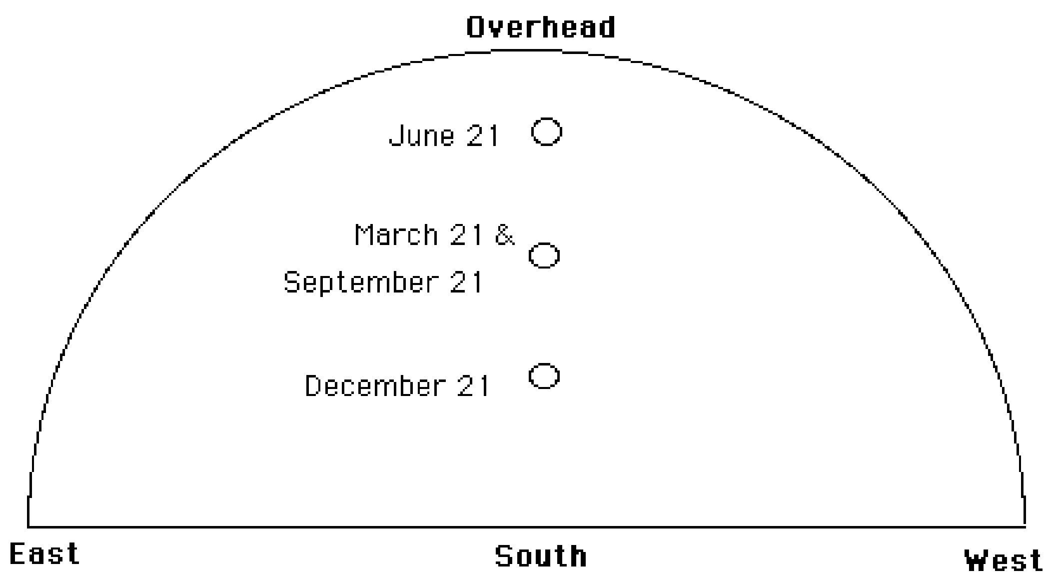

Figure 15-5: Height of the sun in the sky at noon at various dates
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Discrepant Event Activities in Earth in Space

After determining the prior knowledge students bring to the classroom about the Earth in space, instructional activities should be written using their prior knowledge as a starting point. The activities below relate to one or more alternative conceptions about the Earth in space. The following are examples of discrepant events appropriate for the Exploration Phase of a learning cycle lesson. The numbers of the alternative conceptions indicated below match those given in the list above.

1. Student alternative conception. *Day and night are caused by the Sun going around the Earth. The Earth rotates in 24 hours.*

Discrepant Activity A: The following activities should be done as a unit with young students or as an introduction to a unit for older students. With younger students, begin by taking the students outside on a sunny day. Find a tall object like a flagpole or the top of a building or a tree. Ask the students to outline its shadow on the ground using chalk or string. When they have completed this task, ask them a thought question such as: Do shadows stay in the same place? What causes a shadow? Can you tell me (predict) where the shadow of an object will be at a later time? After a few minutes, ask the students to observe the shadow that has been outlined. Have them compare the original outline with the current position of the shadow. Ask them: What is happening? Why has it happened?

When working with older students, place them into groups of three. Ask each group to make a prediction and plan a test to check the prediction. The prediction should describe the length of time it takes for the Sun to start at one place in the sky and return to the same place on the following day. The students may devise other methods, but a simple one involves outlining the shadow of some tall object outside the classroom on a clear day, noting the exact time, and returning the next day to time the return of the shadow to the original mark. When the students have devised their plan, ask them: What is a shadow? What do shadows tell you about the source of light causing them? Check the outlined shadow and determine its location after ten minutes. Why does the shadow move?

Discrepant Activity B: It is useful to have students check their beliefs about the motion of objects against reality. This can be done in a thought experiment. Ask the students to imagine sitting in the family car as it rides smoothly down the highway. As they look out the side of the car, they may see bridges, houses, or trees moving backwards. Ask the class: What is happening here? What is moving? If you were only allowed to look out the side of your car without knowing whether the vehicle was moving or not, could you tell if the scenery was being moved past you or if you were moving past the scenery? Focus on students' statements that report it may not be possible to know whether you are moving or the scenery is moving. What you are seeing will be the same no matter which one is moving. This illusion can be demonstrated by having the students watch a videotaped clip that shows scenery moving by a window such as scenery outside of a train, a car, or a plane. As they are observing the clip, ask them to provide evidence indicating which is moving, the scenery or the vehicle from which the scenery is viewed.

_In the Invention phase of the lesson, relate the discrepant activities provided in the exploration to the idea that we are standing on a platform called the Earth that is moving us past objects viewed in the sky such as the Sun. The students will have discovered in Discrepant Activity A that within experimental error, the Sun's shadow returned to the same spot in 24 hours and zero minutes. The accuracy of their observations can be increased by using a tall object. Students may have difficulty determining when the edge of the shadow returns to the same spot because shadows have a fuzzy edge.

Standing on the Earth, it is not easy to determine whether the Sun is moving or the Earth is moving. From what the students discovered about moving objects in the exploration, they should be able to determine the eastward direction of the Earth's motion. For younger students, the Sun may appear to move toward a line of trees on the far side of the school. In a car the scenery appears to be going in the opposite direction that you are traveling. This analogy can be used to determine the direction that the earth is turning past the Sun. For older students, the westerly motion of the Sun can be determined using a compass. The students should then be able to determine the actual direction of the Earth's rotation as opposite of the Sun's motion. The Earth turns eastward for an observer standing on its surface. This fact does not have to be memorized. Students are able to construct it for themselves, knowing that the Sun always sets in the west.

2. **Student alternative conceptions.** *The Earth is flat. The Earth is round like a pancake. The Earth is round and it is in the sky. The Earth is spherical and people live in a flat place on top.*

Discrepant Activity: Form groups of three. Ask the groups to discuss and develop a response to the following questions.: What is the shape of the Earth? What evidence can you give to convince someone else that your view is correct? Ask students to draw and write out responses to these questions. Have the students report their responses to the whole class.

Following this discussion, provide each group with a very large round balloon and small toy sailboat, or a cutout drawing of such a toy. The toy should be two inches or less in length. Ask the students to blow up the balloon. Then have one student in each group press a cheek into the side of the balloon so that his eye is just at its surface. Have the student describe what he sees. Each of the other students in the group should have the same experience.

Have the students repeat the same experience. This time, the toy sailboat should be placed near the student's eye and then moved slowly around the balloon. Have each student report what he sees as the sailboat moves away from his eye.

Next, start the sailboat on the side of the balloon and move it toward the student's eye. Ask the student to report what he sees. Repeat this experience with all students in the group. Ask the students to compare these results with the ideas they had in their earlier discussion about the shape of the Earth.

The students should find that placing the side of their face into the balloon will create a flat world with a horizon that forms a ring or disk around their eye. The bottom of the sailboat, as it moves away from the student's eye, gradually disappears leaving only the top of the sail visible. Eventually, even the top of the sail disappears from view. In the Invention report to the students that sailors today observe this effect when they watch a sailboat through a small telescope or binoculars. This begins to occur at a distance of about 12 miles on a flat surface on the Earth, such as the ocean. It also occurs in a desert or on a plain. To the observer, the Earth appears to be a disk about 12 miles in radius. Other sources of evidence are pictures of the Earth's shadow on the Moon during a lunar eclipse. Have the students discuss and observe the spherical shape of other objects such as the Sun and the Moon. They should have access to a number of photographs and videotapes showing the Earth from space.

Confrontation activities similar to the ones in the above discrepant activity are necessary to help students examine their beliefs about the world and replace a more primitive conception of the Earth's shape with one closer to reality. The larger the balloon, the more successful the activity will be. Lightman and Sadler (1988) used a weather balloon obtained from a science supply company. They found the activity quite effective in replacing students' alternative conceptions.

3. **Student alternative conceptions.** *The Moon is stationary, does not move, and is located in a part of the sky that is always dark. The Moon goes around the Earth in a single day.*

Discrepant Activity A: Form groups of three. Ask the groups to discuss and develop a response to the following questions: Is the Moon visible in the sky today? What does the

Moon look like in the sky? When is the Moon visible during the day? Ask the students to write out their responses and to illustrate their ideas. Have them report their ideas to the whole class. Ask students to verify their predictions by creating a plan to get evidence to support them. For example, if they predict the Moon is visible in the night sky, they should plan to observe the sky that night.

Discrepant Activity B: Use the groups from Discrepant Activity A. Ask them to discuss and develop a response to the following questions: Does the Moon move during the day? Can we see its motion? If so, draw how the Moon moves when it can be seen in the sky. If it moves, what is the cause of its motion (for older students)? Ask the students to write out their responses and to illustrate their ideas.

With the Moon visible in the daytime sky, plan a short field trip to the school grounds on a clear day. Ask each student group to make a sketch of the sky and the horizon, including the location of the Sun and the Moon and the objects visible on the horizon. For elementary school students, this drawing is made in the morning and repeated during recess, lunch, and in the afternoon. Each field trip will take less than ten minutes. For middle school students, an observation at the beginning of the period and near the end of the period is possible. An additional observation could be requested of the students during lunch or after school. Following the observations, have the student groups compare their findings with their predictions.

_The students in Discrepant Activity A confront their idea of the Moon's visibility with reality. The Moon is almost always visible. The only time it is not visible is about three days around the new phase. Since it takes 28 days to revolve around the Earth, it should be visible on any clear day for 25 days of that period. It is seen in the evening sky when its phase is waxing crescent to full. It is seen in the daytime sky between full moon and waning crescent. Discrepant Activity B should be planned for a clear day when the Moon is in its third quarter phase. At this time, the Moon is visible in the sky 90 degrees west of the Sun. It is visible in the sky during the day between 6:00 a.m. and 3:00 p.m. Check a calendar for the time of the month when this occurs. During the activity, the students' original ideas are confronted with the noticeably quick motion of the Moon. It moves about 15 degrees in an hour or about 30 moon diameters. The Moon moves in a westerly direction.

4. Student alternative conceptions. *The Earth revolves around the Moon. Different countries see different phases of the Moon on the same day. Phases of the Moon are caused by a shadow from the Earth.*

Discrepant Activity: Do this activity two weeks before a lesson is planned for the phases of the moon. It is best to choose a time when the Moon is just past full and visible in the daytime early in the morning sky in the east. Repeat the beginning activities in Discrepant Activity B above from Student Alternative Conceptions number 3. Ask the following questions before groups begin the activity: Where is the Moon in relation to the Earth and Sun? Draw its location in the sky at the same time over a period of many days. What evidence do you have to support your statement? Does the Moon have a motion other than that due to the Earth's turning (rotation)? Do different countries see different phases of the Moon on the same day? What causes the phases of the Moon? Devise a plan to get evidence to support the statements just made.

As in Discrepant Activity B above, after students report their plans to the class, begin observing activities with the Moon during school hours. These observation activities will be different in that the students observe and record in a pictorial format the daily location and shape of the Moon for about ten days at the same time of day. Ask each group to complete a log entry in a journal for each observation. If some days are cloudy, there may be gaps in the record. Since a weekend will fall during this period, the group may not have records for a Saturday and a Sunday, although home assignments should be given. The observations end when the thin crescent moon is invisible in the bright glare of the Sun. Following the observations, have the student groups compare their findings with their original answers to the key questions. When the journal is complete, ask the students to fill in days where there are gaps in the records due to clouds, with an illustration predicting what the Moon would look like if it were visible on that day.

_______During these observations, if they are begun just after a full moon, the Moon moves eastward in the sky each day toward the Sun. The motion is approximately 12 degrees per day. As the Moon approaches the sun, its shape turns from a football (gibbous) shape to a crescent shape only partially lit up and very close to the Sun in the sky. Following this time, the Moon passes under or over the Sun, but so little of its visible surface is lit up and it is so close to the Sun that it will not be visible. In a few days, if the students are instructed to look at the western sky just after sunset, they should be able to see a thin crescent west of the Sun. With continuing observations, the students will find the Moon moving away from the Sun each evening and getting larger.

For the Invention phase of the lesson, ask the students to compare their data and answers to their textbook's discussion of moon phases. Give them balls representing the Earth, Sun, and Moon and help them use the balls, in the bright light of an overhead projector, to construct a model showing the Earth, Sun, and Moon alignment for each of their observations of the Moon in the sky.

5. Student alternative conceptions. *The Sun is directly overhead at noon. The amount of daylight increases throughout the summer months.*

Discrepant Activity: Form groups of three. Provide the students with a sheet of paper with a large half circle drawn on it (see Figure 15-6). Ask the groups to discuss the following questions and illustrate their answers on the half circle drawing: "Where is the Sun at noon today?" "Where is the Sun early in the morning and late in the evening?" Have students draw the path of the Sun throughout the entire daytime period. The hours of daylight do not remain the same throughout the year. There are more hours of daylight in the summer than in the winter in North America.Ask students, "Why does this happen?" When the illustrations and answers are complete, ask students to report their ideas to the whole class. Ask students to verify their predictions by creating a plan to get evidence to support them. For example, if they predict the Sun is overhead at noon, they should plan to observe the Sun in the sky at noon.

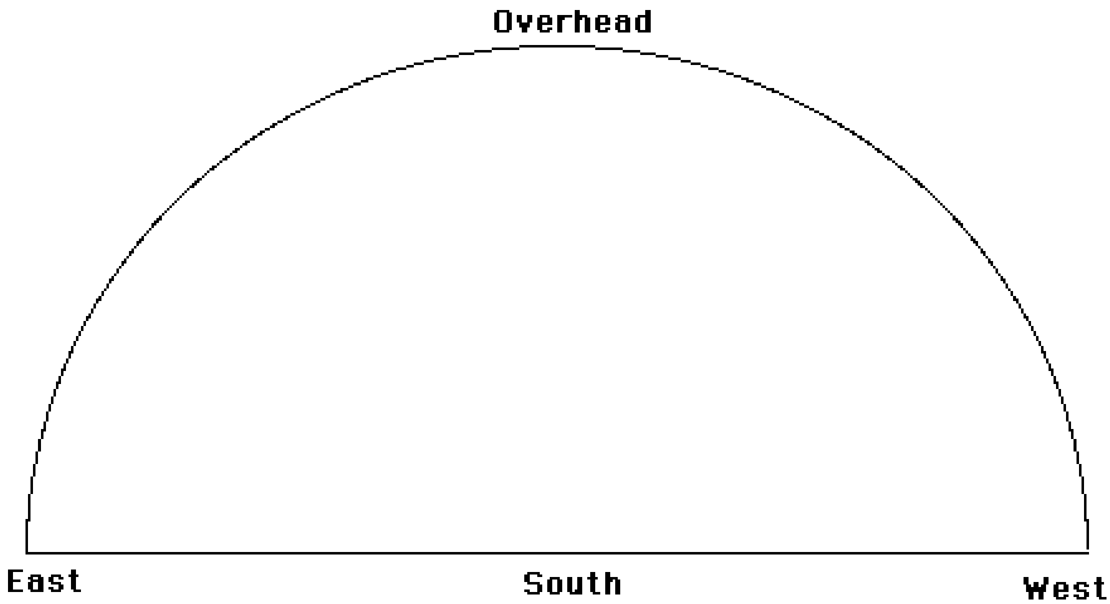

Figure 15-6: Half circle for students to record observations of the sky.

With the Sun visible in the daytime sky, plan a short field trip to the school grounds. Give each group an enlarged copy of Figure 15-6. Ask each group to make a sketch of the sky facing south on their copy of the figure. Include the location of the Sun and principal objects visible on the horizon. For elementary school students, this drawing could be made in the morning and repeated hourly throughout the school day. Record all observations on the same drawing. Each drawing of the Sun should include the date and time. A compass should be used by each group to find the local direction of east, south, west, and north. **Warn the students that they are not to look directly at the Sun for any length of time.** The Sun's rays are so powerful that they will damage retinal cells if any extended observations are directly made. Each field trip will take less than ten minutes. For middle school students, an observation at the beginning of the period and near the end of the period would work best. Additional observations could be requested of the students during lunch or after school, or as a homework assignment to be done hourly on a Saturday. Following the observations, ask student groups to compare their findings with the predictions they made earlier in response to the key questions.

_______Students typically make a prediction that the Sun will be overhead at noon and rise directly in the east and set in the west. Their observations will not confirm this prediction. For students in the third grade and above, bring a compass outdoors and allow them to determine exactly where on the school grounds south, east, and west are to be found. For younger students, tell them how to stand to view the southern sky.

For a winter sky, students in North America (anywhere in the northern middle latitudes) will find the Sun to be less than halfway to the zenith. It will rise in the southeast and set in the southwest. During the school year only in April and May does the Sun rise in the northeast and set in the northwest. The Sun will never be overhead. For students in the USA and Canada (except Hawaii), the Sun is never overhead, even during the summer.

6. **Student alternative conceptions.** *The Earth revolves around the Sun. The Earth is in the center of the solar system. The seasons are caused because the Earth is closer to the Sun*

in the winter.

Discrepant Activity: Form groups of three. Provide each group with a current monthly star chart. Monthly star charts are found in books on astronomy and in Science and Children, a publication of the National Science Teachers Association. Ask groups to find three of the most prominent constellations, name them, and locate the position in which they would be seen in the sky. Next, give each group last month's star chart. Ask them to note the differences in location of the same three constellations. Ask, "In what direction do the constellations seem to be moving during the two months -- westward or eastward?" Predict where the three constellations will be next month.

When the groups have arrived at their answers, ask them to share their ideas with the rest of the class. There should be some differences in the groups' predictions. Students may be surprised by the answers to the previous questions. Now ask, "Why have the constellations changed their positions from month- to-month in the star charts?" When they have arrived at an answer to this question, give the groups a third sky chart. This chart should show the sky as it appeared last year during the current month (this can be done by taking the current star chart and blanking out references to the current year since the stars will appear in the same location each year over a lifetime.) The students should be surprised when they see this new star chart. But it should fit into an appropriate explanation. __

__________Following these activities, begin the invention phase of the lesson with a whole class report from each of the groups regarding why the changes occurred. Make facilitative and informational comments during this reporting period.

The students will find that the constellations they choose move about thirty degrees westward each month. This is a significant change. As an alternative to the above activity, or in addition to it, ask students to observe and draw on Figure 15-6 a prominent constellation in the night sky on a biweekly basis over a six week period. They will note the same effect.

For the in-class activity, the students should have little problem predicting where the constellations they have chosen will be a month from now. The motion is obvious. The students should be perplexed about the fact that a year before, stars looked the same as they did currently. It will only make sense to them if they conclude that the Earth is in an orbit around the Sun and returns to the same spot each year. If we look out from the dark side of the Earth into the sky, we should see the same constellation in the same part of the sky. This is like sitting on a merry-go-round looking away from the center at people standing around. Every time we make a complete revolution, we should see the same people standing there if they have not moved. At this point, it would be useful to ask the students, "Which way is the Earth revolving around the Sun?" Ask the students to point out the direction on the star charts that are laying in front of them. They should have the previous month's chart on their left side and the current month on their right side. They should have indicated that the stars are moving westward monthly as they've determined by observing the sky at the same time each evening. For this to occur, the Earth must be revolving eastward or to the left. Use the analogy of a student walking by rows of chairs in a classroom. If the student is walking toward the back of the room, the chairs will appear to be moving toward the front of the room for an observer who is not aware that he is moving. Another analogy is to use a girl looking out of the side window of a car at trees and houses moving backwards as the car moves forward. If we know the background is stationary, we can always tell the direction of our motion.

Implications for Classroom Teaching for a Unit on Earth in Space

Much information that students understand about the Earth in space is derived from their own sensory experiences and their social world. They need to distinguish between information derived through various aspects of the social world and scientific observation. Part of the information students perceive in the everyday world through their senses, television, story books, magazines, and adults contains inaccurate, misleading, and partial statements of scientific fact. Even though students may have covered space topics in classroom units in previous years, much research points to the fact that only a small portion of students learn and use appropriate space concepts in their daily lives (Driver, Squires, Rushworth, & Wood-Robinson, 1995). More typically, students base their ideas of the Earth in space on alternative conceptions or a mix of everyday knowledge and school knowledge. Helping students construct conceptions about the Earth in space more closely related to scientific fact can be fostered by:

1) providing activities involving daytime and night time naked-eye observations and observations with instruments, where possible. Experiences with observations of many earth-related and astronomical events help students develop an experiential basis for the appropriate use of models (e.g. Earth globe, Moon in orbit around Earth, and the Earth in orbit around the Sun). Students using models without having background observational experiences generally do not meaningfully learn.
2) spending a good deal of time experiencing, obtaining information, classifying, and predicting change in a wide variety of astronomical and Earth-related events (see discrepant activities above for some ideas),.
3) providing opportunities for students to compare their everyday knowledge and experiences about the Earth in space with models, concepts, and generalizations based on scientific evidence.
4) giving students many opportunities to use scientifically accepted ideas about the Earth in space. Students need to work out how to apply these ideas to a wide range of situations. They begin by relating familiar experiences of observing the sky to star maps and models and then relating the models back to their experiences. Then they relate their experiences and the models to theory and then relate theory back to experiences and models. This process leads to the application of theory in a wider range of situations. These opportunities involve the potential for extensive writing, listening, and speaking activities. The activities might include storytelling narratives of observations such as describing what actually happens to the moon when viewed hourly throughout the evening, telling of an experience of standing at the ocean shore and looking at the horizon trying to see the curvature of the Earth, and planning and carrying out predictions to test the difference between competing ideas.

What experiences are helpful in developing students' ideas in the area of earth in space? The objectives of an earth in space unit relate to helping students understand the view of space they have from Earth. They are based on scientific evidence from numerous observations and the accumulation of facts made by other observers. Do this before providing extensive explanations: Ask small groups to share their ideas of space through drawings. They could be asked to "Draw an astronomer," "Draw the Earth," "Draw the solar system as you understand it," or "Draw the inside of the sun." Only after such exploration of <u>their</u> ideas and many personal observational experiences should students be introduced to analogies and models. The limitations of analogies and models should be clearly made. Finally, concepts and generalizations should be identified and planned for in later learning cycles that will relate to the observations and use of models completed in these earlier, perhaps skills-oriented, lessons. Concepts and generalizations must be constructed through direct evidence that leads to critical thinking. Begin a unit with a hands-on lesson on the key question such as "What does the sun do during the daytime? Draw and explain your drawing." For older students, asking, "How do know that the Earth is a sphere?" "What evidence would you be able to get to demonstrate that the Earth is moving in an orbit?" is a start in this direction.

Time for Reflection: What Do You Think?
Student Interview on Earth in Space

Assess and discuss the prior knowledge of one or more students in a conceptual area related to the Earth in space. In advance, set up a schedule with a teacher that will not interfere with normal class activities. Take notes during the interview, and later, complete a reflective journal entry for each student about the interview. Discuss the results with the teacher and observe the student in his daily activities to see if the student's thinking fits your conclusions. Follow these steps when completing the activity.

Step 1. Select a discrepant event, phenomenon, or confrontational situation related to an Earth in space concept or generalization. Use the alternative conceptions and activities above as an example of the content and format needed for your student. Consider the probable prior knowledge of this student when planning the activity. Gather the demonstration materials or draw the phenomenon or situation.

Step 2. Write a script of the key question and possible follow-up responses you will make. Consider general open-ended questions, problem solving tasks, garden path tasks (walking students through the idea), or comprehension tasks. Ask the student to describe her understanding of the event. Use one of the discrepant activities described above or construct one using a similar format.

Step 3. To start the interview, set the student at ease. Talk to the student about something of interest. Begin the interview with your key open-ended question.

Step 4. Find out what ideas the student already has about a phenomenon or situation. Ask, "What do you think is happening?" "For what reasons?" Note the words the student uses to explain or describe it. Focus on the student's response and the reasoning that led to the answer.

Step 5. Take the student seriously. Give her the opportunity to discuss or try out ideas by herself.

Step 6. Challenge the student to describe or find evidence for her own ideas. Probe the student and follow her line of reasoning.

Step 7. Thank the student for allowing you to listen to her view of the event. After the interview, write up the events as they occurred from Step 1 to Step 7 in a reflective journal form.

Step 8. To complete this activity, include a title page and label the parts of the assignment indicated below.

1) A description of the concept or generalization and the demonstration materials or a drawing of the phenomenon or situation.
2) A script of the key question and possible follow-up responses you will make to your students.
3) Write up notes of the interview events as they occurred in reflective journal form. Identify the student by first name only.
4) Concluding paper -- write your conclusion and a prescription in a typed one paragraph format. Consider the following questions: What does the student believe (prior knowledge) about the concept or event? Why does she believe this? How does this belief relate to the scientific view? What have you learned about this student as a teacher?

A Learning Cycle Involving Student Alternative Conceptions Related to the Earth in Space

In order to demonstrate the complete instructional process of: 1) identifying students' alternative conceptions, 2) developing a lesson plan, and 3) developing an assessment for a specific concept in earth in space, an example of a complete lesson and assessment follows.

Alternative Conception Addressed by the Lesson Plan:
The Sun is directly overhead at noon. The daylight is the same length as the local day on any part of the Earth (alternative conception number five above).
Lesson Goal: To allow students to investigate and develop inferences about the orientation of the Earth in relation to the Sun.
Grade Level: Grade 4 or 5
Prerequisites: Can measure height to the nearest centimeter. Knows the cardinal points of the compass.

Exploration:

Objective: Students will make inferences about the location of the Sun in the sky when seen from the Earth.
Materials: For each group: one copy of Figure 15-6
Procedure:

A. Organize small groups of three students: a materials manager and reporter, one observer, and one illustrator. Rotate roles rotate over time.
B. Describe the materials and instructions needed to carry out the activity. Provide each group with a sheet of paper with a large half circle drawn on it (see Figure 15-6). State the key questions, write them on the board, and ask each group to discuss and complete their answers by drawing on the half circle. "Where is the Sun at noon today?" "Where is the Sun early in the morning and late in the evening?" Draw the path of the Sun throughout the entire daytime period.
C. When the students have completed their work, ask the reporter from each group to present their results to the entire class.
D. Ask the groups to discuss the following questions written on the board: Is the amount of daylight hours the same for all people on the Earth today? In the winter, there are fewer hours of daylight than in the summer. Why does this happen? Ask the students

to write out their responses and illustrate their ideas. Also, ask the students to devise a plan for providing evidence for their answers to both questions.

Evaluation: Determine whether each group has a complete response to each question and a plan for obtaining evidence to support their answers to each question. Assess group skills by observing whether students join their groups quickly when asked and whether the group reviews what needs to be done before starting.

Invention:

Objective: Students will investigate and describe the location of the Sun and the duration of daylight over different regions of the Earth.

Materials: For each group: one copy of Figure 15-6, one globe, small lump of clay, and a toothpick.

Procedure:

A. Have each group present their responses to Item D in the Exploration above and their plan for providing evidence for their ideas to the whole class. Help students communicate the results of their discussions using observations to justify their conclusions. Help them compare each group's plan for providing evidence.

B. With the Sun visible in the daytime sky, plan a short field trip to the school grounds. Give each group a large copy of Figure 15-6. Ask each student to make a sketch of the sky facing south and the horizon. Students are to draw in the location of the Sun and important objects visible on the horizon from their location on the school grounds. This field trip can be completed in less than ten minutes. Repeat the activity three to five times throughout the day, twice in the morning, once at noon, and twice in the afternoon. Make each observation hourly. Record all observations on the same drawing. Include the time on each drawing. **Warn the students not to look directly at the Sun.** Damage to the eye can occur in just a few seconds.

B. Write the key questions from the Exploration (part B) on the board. Ask the groups to answer these questions based on their observations. Ask them to compare these answers to the answers they inferred during the exploration. Have them report their comparisons to the whole class.

C. Elicit and explain the discrepancies between the student inferences and the observations they just made. It should be clear to the students that their original ideas may not be supported by evidence they have just gathered. During a brief discussion, ask them how they arrived at their ideas about the Sun's location and motion in the sky. How different were their original ideas from the observations they made?

The Sun is never overhead. The path of the Sun keeps it in the southern part of the sky all day long. During the fall and winter months, the Sun rises in the southeast, moves to a high position in the south, and sets in the southwest. As an additional assignment, ask some students to observe the location of sunrise on a weekend morning while others observe the late afternoon Sun and a third group observes the sunset. Provide students with a compass to help them with directions.

D. The following activity also requires a clear day with a bright Sun. Obtain one Earth globe for each group. The best type of globe to use in this activity is one that is detachable from its stand. Model how students are to use the globe when they go outside. Ask each student group to cut a strip one inch wide and one foot long out of poster board. Form it into a circle and staple the ends together. Demonstrate how to set up the globe. Take the globe out of its stand and set it on the floor into the base formed by the poster board circle (Figure 15-7). Put your city or town location on the exact top of the globe. Point the north pole of the globe toward the direction of north. Instruct the students to do the same with their globes when they go outside. Do this activity outside on blacktop or grass to reduce the glare of sunlight on the globe. Tell students that when the Sun shines on the globe, it replicates the way the Earth looks to an astronaut on the moon. The astronaut would also see parts of the Earth lit up by the Sun and other parts in shadow. He would also see where the day and night come together and the edge of the shadow. The shadow's edge occurs on both sides of the Earth.

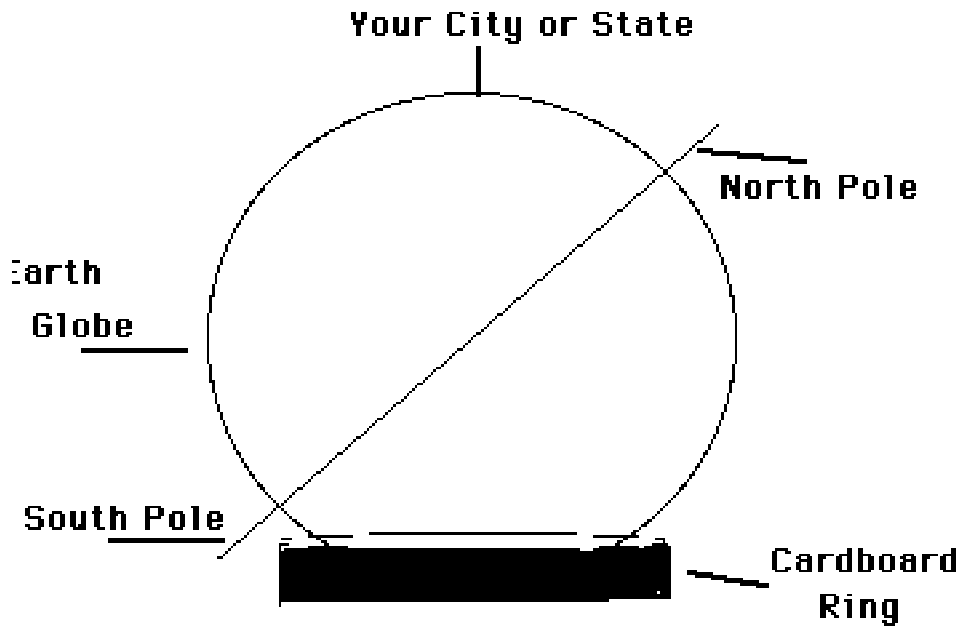

Figure 15-7: Setting up the globe.

To demonstrate a method for students to determine the amount of sunlight any city receives during a day, ask students to find places on the Earth at a specific latitude, for example 40^{o} north latitude, that are turning from night into day and day into night. This is the shadow's edge. Count the number of longitude lines from the shadow's edge on the right side of the earth to the shadow's edge on the left side of the Earth. These longitude lines are generally fifteen degrees apart. This is how much the Earth turns in one hour. If there are ten fifteen-degree intervals from one shadow's edge to the other, there will be ten hours of daylight during a twenty-four hour period at that latitude.

Before taking the students outside, provide each group with a small lump of clay and a toothpick. Then give each group a sheet of paper with the following questions: Where is the Sun overhead right now on the Earth? How many hours of daylight exist for cities in the following latitudes: 50 degrees north? the latitude of your town? the equator? and 40 degrees south of the equator? They can stand the toothpick up in the clay and press the clay onto the globe. Shadows cast as the clay and toothpick are moved to different places on the globe provide information useful in answering the first question. The place where no shadow is cast by the toothpick indicates where the Sun is overhead. Ask students to explain and illustrate the group's answers to these questions.

E. Return inside and have each group report its findings. Discuss these, adding information as necessary.

F. Closure: The Sun is overhead someplace on the Earth at any given time. At night the Sun is overhead someplace on the other side of the Earth. The Sun is never overhead for any portion of the USA, except Hawaii. Cities at different latitudes have differing amounts of daylight most days of the year. Only on March 21 and September 21 are daylight hours (twelve) for every city on the Earth the same. This can be seen on a globe outdoors on these days as the shadow's edge lights up half of the Earth so that the shadow cuts exactly through the north and south poles. At other times, the shadow's edge falls to one side of the poles.

<u>Evaluation</u>: Decide whether each group has a complete response to each question and illustrations that provide evidence to support their answers.. Assess students' group skills by observing whether they stay with their group while it is working and pay attention to how much time they have to carry out each activity.

<u>Expansion:</u>

<u>Objectives</u>: Students will compare the height of the Sun in the sky as seen from different locations on the Earth.

Students will determine that the Arctic and Antarctic are places where the Sun will not rise or set.

Students will determine in what cities on the Earth the Sun is rising or setting at the time of the lesson.

<u>Materials</u>: For each group:

materials from the Invention activity, a thirty centimeter ruler

For each student:

copies of Figure 15-6

copies of a drawing of the whole earth

<u>Procedure</u>:

A. Give the students a handout containing the following directions and information:

Do this activity outside just as you did the last one using a globe, a small lump of clay, and a toothpick. Set up the Earth globe on the cardboard ring so that your state or town is on top and the north pole points north. The length of the shadow of an object gives information regarding how high the Sun is in the sky. Compare the height of the Sun from various locations on the Earth that are north and south of your town. Do this by comparing the length of the toothpick's shadow in various locations. Do this for the following locations: zero degrees (equator), plus and minus thirty degrees, plus and minus sixty degrees, and plus and minus eighty degrees. Record this information on the drawing of the Earth. Where on the Earth today will the Sun never rise? Where will it not set? Name two cities where the Sun is just setting (in Africa or Europe). Name two cities where the Sun is just rising (in Asia or Australia). Record your answers to these questions.

B. As an extended expansion activity, have the students note the sunset and sunrise times over a two week period as reported in the newspaper and comment on the day-to-day changes. Ask the student groups to report their findings to the whole class.

C. Another extended expansion activity involves students in obtaining the sunrise and sunset times for the town's latitude for an entire year. Ask them to record and graph the length of the daylight period on the first day of each month. Have them report their findings to the whole class.

D. Summarize the lesson by reviewing the activities and major findings of the various parts of the lesson.

Evaluation: Ask students to draw the Sun's path on Figure 15-6 during the day from sunrise to sunset. On a drawing of the Earth, ask students to circle the area where the Sun is overhead at this time. On the same drawing of the Earth, ask students to indicate cities where the daylight hours on that day are the greatest and where they are the fewest.

Examples of Alternative Conceptions in Additional Earth and Space Science Areas

Students develop alternative conceptions in earth and space science starting in early childhood. Their observations of the sky and Earth and representations they see on television (especially in cartoons) provide a source for many alternative conceptions. Although some alternative conceptions may relate to their level of development and can be expected to be modified without much intervention, many ideas about the earth and space sciences developed during the elementary school years remain with them throughout adulthood unless directly addressed in effective instruction. The following is a brief sample of alternative conceptions commonly found in relation to earth and space science topics such as the Earth, its structure, history, oceans and atmosphere; space science; geology; the solar system; and stars and the universe. The list demonstrates the depth and breadth of alternative ideas students bring to class. It also indicates that teachers must be aware of students' alternative ideas in order to plan effective earth and space science lessons. For example, see the following reports of research: Phillips (1991); Nelson, Aron & Francek (1992); and Driver, Squires, Rushwater, and Wood-Robinson (1994).

Sample Alternative Conceptions About the Earth Students Bring to Class

The Earth: Its Structure and History

1. *The center of the Earth is made of black rocks because a man who comes out of a hole is covered with dark dirt.* (younger students)
2. *Thrown objects may fall off the Earth when dropped in the southern hemisphere.*
3. *The Earth is sitting on something.*
4. *The Earth is larger than the Sun.*
5. *Molten earth material comes from the core of the Earth.*
6. *Volcanic eruptions always produce steep-sided cones.*
7. *Erosion only occurs on steep slopes.*

The Earth: Its Oceans

1. *Coral reefs exist throughout the Gulf of Mexico and the North Atlantic.*
2. *All rivers flow down from north to south.*
3. *Materials such as salt or sediment dissolved in water do not change their properties.*
4. *Oceans stay the same, they don't change.*
5. *What humans do can't change oceans.*
6. *When water evaporates, it ceases to exist.*
7. *When water evaporates, it turns into another visible kind of thing like steam or fog*

(students do not believe that water can be in the form of a gas, water vapor, which is not visible).

8.*Water in all bodies of water on the Earth freezes at 0^{o} Celsius or 32^{o} Fahrenheit* (due to substances dissolved in rivers and oceans, freezing occurs at lower temperatures).
9. *The sea level remains constant.*

The Earth: Its Atmosphere
1. *Rain comes from holes in clouds. Rain comes from colliding clouds. Rain occurs because we need it.* (younger students)
2. *Clouds come from somewhere above the sky.*
3. *The sun boils the sea to create water vapor.*
4. *Clouds are made of smoke* (younger children).
5. *Clouds are made of water (liquid water filled).*
6. *Clouds are made of water vapor* (older children; however, water vapor is a colorless gas and so it is invisible.)
7. *Air is not a real substance.*
8. *Gases make things lighter.*
9. *Humid air is heavier than dry air so it sinks to the ground.*
10. *Lightning does not strike the same place twice.*
11. *The direction of drainage in a sink or bathtub is always in the same direction* (older students).

<u>Sample Alternative Conceptions About Geology Students Bring to Class</u>
1. *Rocks must be heavy.*
2. *Rocks cannot float* (denser rocks such as continental rock float on mantle rock).
3. *Very light objects have no weight* (examples given are styrofoam and pumice.)
4. *Soil must always have been in its present form.*
5. *There is only one kind of soil.*
6. *All soil looks, feels, and smells the same. Soil is just dirt.*
7. *Soil is the same on top as underneath even in undisturbed soil in the forest.*
8. *Any crystal that scratches glass is a diamond.*
9. *Washington, D. C. could not be severely damaged in an earthquake in the future.*
10. *Mountains are created quickly.*
11. *The continents and oceans of the Earth have always remained the same.*
12. *All radioactivity is made by people.*
13. *Dinosaurs and cavemen lived at the same time.*
14. *Dinosaurs are the largest animals that ever lived.*
15. *Crocodiles and alligators are dinosaurs.*
16. *People are responsible for the extinction of dinosaurs.*
17. *Dinosaurs lived at the same time as ice age mammals like the woolly mammoth and the mastodon.*

<u>Sample Alternative Conceptions About Space Science Students Bring to Class</u>
1. *There is an up and down in space*
2. *Gravity cannot exist without air.*
3. *Gravity requires a material to act through.*

4. *Rockets in space require a constant rocket thrust or force to continue to move.*
5. *Gravity acts differently on various materials.*
6. *Gravity pulls things down* (little concept of gravity as directed toward the center of a spherical Earth).
7. *While in space the Space Shuttle astronauts are not under the influence of gravity* (gravity still exists, they are weightless due to forces of motion and gravity balancing each other).

<u>Sample Alternative Conceptions About the Solar System Students Bring to Class</u>

1. *The Sun ceases to exist at night.* (younger students)
2. *The Sun is not a star.*
3. *The Sun will never burn out.*
4. *The Moon makes light the same way the Sun does.*
5. *The moon increases and decreases in (physical) size.*
6. *Different phases of the moon are seen from different locations on the Earth on the same day.*
7. *Phases of the moon are caused by the Earth's shadow or by passing clouds.*
8. *Summer and winter seasons are the direct result of the Earth's distance from the sun.*
9. *Planets appear to the naked eye as a small disk.*
10. *The solar system appears to us <u>from Earth</u> as a set of concentric orbits, circles, revolving around the Sun and seen from the top.*
11. *The Sun is smaller than the Earth.*
12. *The solar system is composed of galaxies, stars and planets.*

<u>Examples of Alternative Conceptions About Stars and the Universe</u>

1. *The universe is always the same.*
2. *The universe contains only the planets and stars in our solar system.*
3. *Stars are all the same distance away.*
4. *Stars are the same. They are not different in any significant way.*
5. *Stars are smaller than the Earth. Stars are small bodies much smaller than the Sun.*
6. *Astrology, based on star and planet location, is able to predict the future.*

Time for Reflection: What Do You Think?

Evaluate one of your earth and space science lesson plans, or a science textbook chapter. Determine possible alternative conceptions students may bring to class related to the content to be taught. You may want to evaluate the lesson plan used in the previous **Time for Reflection**: **What Do You Think?** If possible, work with a partner on this activity. Answer the questions below:

1) What are the stated or implied focus concepts and generalizations in the lesson plan or chapter?

2) What are possible alternative conceptions students might bring to class? Check the lesson concepts and generalizations against the sample lists provided above as a beginning. List the alternative conceptions.

Activities That Can Help Students Change Their Alternative Conceptions in Earth and Space Science

Discrepant events can provide students with the confrontation they need to test out their prior knowledge. The discrepant events provided below demonstrate examples from each earth and space science area. A sample alternative conception is followed by an appropriate discrepant event useful during the Exploration Phase of a learning cycle lesson.

<u>Discrepant Events With the Earth: Its Oceans</u>

Student Alternative Conceptions:

6. *When water evaporates, it ceases to exist.*
7. *When water evaporates, it turns into another visible kind of thing like steam or fog*.

Discrepant Activity: Form groups of three students. Give each group 5 ice cubes each placed as follows: put one ice cube on a plate, a second on a sponge, a third on a piece of construction paper, a fourth on top of potting soil in a styrofoam cup, and a fifth in a jar with a lid on. Ask each student group to illustrate and describe their observations. Ask them to discuss and come up with a response to the following questions regarding what happens when ice cubes melt in different locations: "What is happening to each of the ice cubes?" "What happens to the water dripping from the ice cubes?" "Where did the water go?" Ask students to examine their ice cubes one hour later and to respond to each of the questions again. Have the groups report their results and ideas to the whole class.

______This activity elicits student ideas related to ice turning to water and finally disappearing either by absorption into a material or by evaporation into the air. When water evaporates it forms a gas that is invisible (water vapor). Fog and steam are a physical form of water in the liquid state. It is in small water droplets. Water vapor is a gas whose particles are the size of molecules. Neither evaporation nor water vapor can be observed. Only the results of their presence can be seen in the coolness that results when water evaporates, decreased water volume, or the disappearance of wetness in an object that has absorbed water.

<u>Discrepant Events With the Earth: Its Atmosphere</u>

Student Alternative Conception:

3. *The Sun boils the sea to create water vapor.*

Discrepant Activity: Form groups of three students. Give each group a tall, straight-walled glass or bottle. Ask each group to fill the container about three-fourths full of water. Then, have them set it on the windowsill or in a location in the room where it will not be disturbed for a few days. Have students mark the level of the water with a marking pen and write the name of their group on it. If the containers are in a sunny location, the results are more quickly seen than if the container is in a darker or cooler location. Ask the students to keep a record of the water level twice a day over the next three to four days. Each day have one of the groups carefully put a thermometer in their container and measure its temperature. The water level, temperature, and the date of each observation should be recorded on the glass.

______The students who expected little to happen should be surprised at the amount of evaporation of water from their open containers. Measuring the temperature confirms that 100^{o}

Celsius (212^{o} Fahrenheit) was never achieved in these containers. Yet the water disappeared or evaporated from the surface of the water in the container. This consistently happens in the oceans at temperatures far below boiling.

Discrepant Events With Space Science

Student Alternative Conception:
8. *The Earth's gravitational attraction extends only to the edge of the atmosphere.*
Discrepant Activity: Give each student a sheet of paper with a 10 centimeter (four inch) diameter Earth circle drawn on it. Ask them to draw where the atmosphere ends (one millimeter or 1/20th of an inch on this scale) and how far out the Earth's gravitational attraction extends. Explain these directions in terms of the students' level of understanding. When they have completed their illustrations, have them write a description of the meaning of the illustrations. Now, ask the students to work in groups of four. Have them describe their answers to each other. Following the discussion, ask each group to discuss and come up with an answer to the following: "The Moon is about 400,000 kilometers (240,000 miles) away or about thirty Earth diameters away (30 times four inches = 120 inches away on this scale) and revolves around the Earth once a month. What keeps it in its orbit around the Earth? Compare your answer to this question to the earlier questions."

______Older students find their answer to the moon question perplexing. Because of the mass media's emphasis on: weightlessness, zero gravity, or microgravity in space-related articles (especially when discussing Space Shuttle trips), most students believe that gravity ends with the atmosphere. There is gravity everywhere on Earth but none just above the atmosphere for the Space Shuttle. Therefore, gravity ends with the atmosphere.

The Moon is held in its orbit by the Earth's gravity. If no other forces from other bodies intervened, the Earth's force and the effect of gravity would extend infinitely. Gravity becomes weaker with distance. If the distance is doubled, the gravitational force becomes one-fourth as strong. However, the force is still strong enough to affect huge bodies in space such as the Moon. The Space Shuttle is on average only about 250 kilometers (150 miles) above the Earth's surface. This is very close to the Earth. The Shuttle has traveled into space a distance equal to less than two percent of the Earth's diameter. The Moon is thirty times the Earth's diameter away. Gravitational attraction at the Shuttle's distance from Earth is nearly equal to (about 93%) Earth's attraction on its' surface. The orbital motion of the Space Shuttle causes the Earth's gravitational force to be balanced by a force due to orbital acceleration. This balance results in weightlessness when orbiting around the Earth.

Discrepant Events With Geology

Student Alternative Conception:
2. *Rocks cannot float* (denser rocks, such as continental rock, float on mantle rock).
Discrepant Activity: Form groups of three. Ask the groups to discuss and develop a response to the following questions: What happens when you pour liquids of different types into the same container? What is the evidence that you can give to convince someone else that your view is correct? Draw and write out responses to these questions. Have the students report their responses to the whole class.

Following this discussion, provide each group with a tall, narrow container such as a cylindrical olive jar or small diameter juice glass. Ask the group manager to use a marking pen to mark the group's container with two lines 1/3 of the way up and 2/3 of the way up. Ask the materials managers to take the container to the station marked "cooking oil." Have each fill the container to the first line (1/3) with cooking oil and take it back to the group so that observations of the first liquid can be made. The group should make and record at least ten observations (for example, its color, odor, quickness of flow, bubbles, size of bubbles, and how fast bubbles move).

Next, the materials manager should go to the station marked "water" and get a six ounce drinking cup full of water. Ask the group to make ten observations of the water as the second liquid.

Following the observations, have the materials manager pour the water into the cylindrical container of oil until the second line (2/3) is reached. Ask the group to make ten observations of the pouring process and of what happens after the water is poured.

The materials manager should get a small object from station three. An object that can be used is a 1/2 inch plastic square cut from the top of a margarine container or other type of thin plastic. After making group observations of the object, the materials manager puts the object into the oil and water container. Ask the group to discuss and answer the following questions. What happened when the two liquids were put into the same container? How does the word "floating" relate to what you see in the two liquids? What happened when you put the object into the two liquids? How does the word "floating" relate to the object? Can solids float in a liquid? Can liquids float in liquids?

______Students find the mixing of liquids interesting. Most will not have predicted the results of the oil floating on top of the water when the two are put together. Putting the object into the water and oil container enables students to see that the object sinks through the oil and stops at the water boundary where it floats on the water's surface. These concepts are necessary if students are to be able to make sense of concepts in geology. They relate to molten rock flowing up out of fissures onto land, the continental block of land that makes up North America floating on the denser rock of the mantle (the invention for this discrepant event should lead to this concept), and continents moving over the surface of the Earth due to upwelling currents in the mantle (plate tectonics).

Discrepant Events With the Solar System

Student Alternative Conception:

8. *Summer and winter seasons are the direct result of the Earth's distance from the sun.*

Discrepant Activity: Place students in groups of four. Ask them to discuss and come up with answers to the following questions: What is the cause of seasons? Why is it warmer in summer and colder in winter? Have them write and illustrate their responses on a sheet of paper and save them for presentation to the class later.

Give each group a compass, a sheet of paper with a dot for the Sun in the middle, and a ruler. Ask them to draw the Earth's orbit to scale. Provide them with the approximate distance of the Sun from the Earth at its maximum or 157,500 kilometers (94, 500,000 miles) and minimum of 152,500 kilometers (91,500,000 miles). Try 30,000 kilometers equals one centimeter as the scale for the drawing. They may need help scaling this orbit to the size of the paper. When they are finished, ask them to think about the above questions. Would they like to revise their answers to the questions? If so, ask them to write their second responses below the first ones.

______Many of the students will have alternative conceptions as to the cause of seasons. Eliciting them and making them public in the Exploration phase of the lesson is important. The circles they draw for orbits should make it obvious to them that the difference in distance between the Earth and the Sun in various parts of the Earth's orbit is insignificant when compared to the average orbital distance from the Sun. The invention leads to the investigation of an explanation of the cause of seasons based on the sun's altitude and length of day in different seasons.

Discrepant Events With Stars and the Universe

Student Alternative Conceptions:

3. *Stars are all the same distance away.*
4. *Stars are the same. They are not different in any significant way.*
5. *Stars are smaller than the Earth. Stars are small bodies much smaller than the Sun.*

Discrepant Activity: This activity works best following an introduction to stars for grades 5 - 8. Ask all students to write and illustrate the following. Draw each of these to the same scale: Earth, Sun, North Star, and the star, Betelguese, in the constellation of Orion. Describe how these four objects differ from each other. Place students in groups of four and ask them to share their drawings and responses in their groups.

Next, ask each group to complete the following activity. Give each group a copy of Table 15-1 and Figure 15-8. Table 15-2 lists the brightest stars in the constellation of Orion and the important characteristics of each star. Figure 15-8 represents the location of each star in the constellation of Orion. Ask every group to illustrate the size of the Sun, Betelguese, and Rigel using the information in Table 15-2.

In addition, assign each group a different characteristic of the stars in Orion found on Table 15-2. They should make an illustrated presentation to the class of the differences found between stars with this characteristic. The characteristics are: brightness as seen from the Earth, companions, color, distance, and brightness compared to the Sun. A magnitude 1.0 star is 2.5 times brighter than a magnitude 2.0 star. The letters associated with color are the names given to each color group, so spectrographic classification "B" signifies a bluish star.

Table 15-2

Stars in the Constellation of Orion

Name	**Brightness** seen from Earth (magnitude, 0 = brightest)	**Color** (OBAFGKM, Blue to Red)	**Distance** from Earth (light years)	**Companion** Stars (multiple star)	**Size** Compared to the Sun (xSun)
Betelgeuse (Alpha)	0.7	M, reddish	520	1	700
Rigel	0.1	B, bluish	900	3	50

(Beta)

Name	**Brightness** seen from Earth (magnitude, 0 = brightest)	**Color** (OBAFGKM, Blue to Red)	**Distance** from Earth (light years)	**Companion** Stars (multiple star)	**Brightness** Compared to the Sun (xSun)
Bellatrix (Gamma)	1.6	B, bluish	470	0	4,000
Mintaka (Delta)	2.2	O, bluish-white	1,500	1	20,000
Alnilam (Epsilon)	1.7	B, bluish	1,600	0	40,000
Alnitak (Zeta)	1.8	O, bluish-white	1,600	2	35,000
Saiph (Kappa)	2.1	B, bluish	2,100	0	50,000
Pi-3	3.2	F, yellowish	26	0	3
Lambda	3.4	O, bluish-white	1,800	1	9,000

Table 15-2: Characteristics of stars in the constellation of Orion

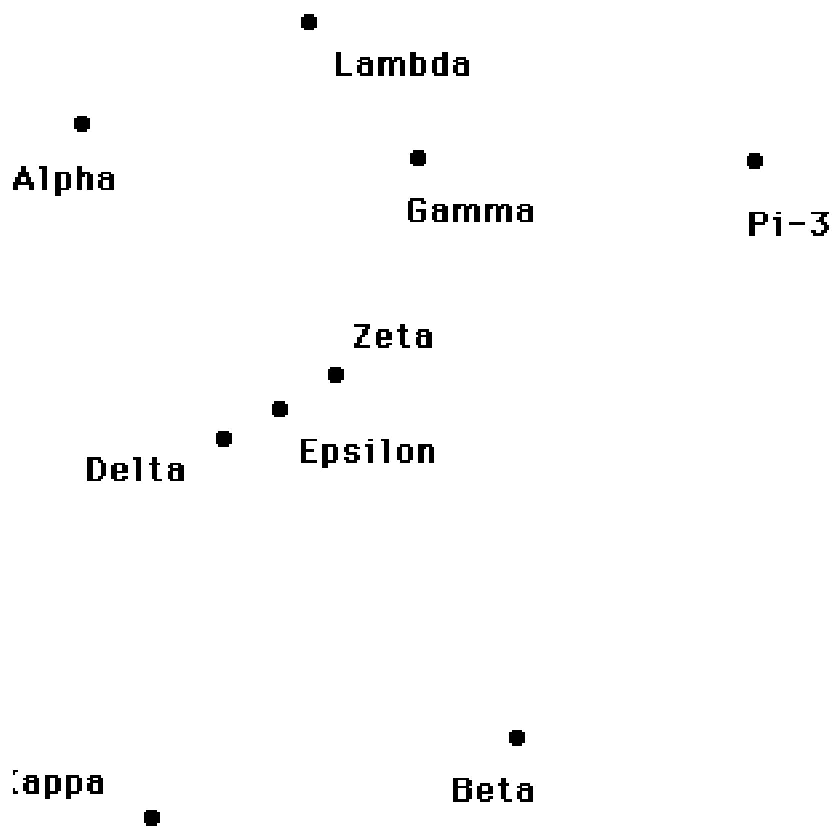

Figure 15-8: The stars seen in the constellation of Orion.

______Most students do not appreciate the differences between stars and what those differences represent. It is important to get students to discuss their own beliefs about stars. At the beginning of the invention, provide students with the following information about the approximate sizes of the objects they drew earlier.

Earth 8,000 miles in diameter
Sun 865,000 miles in diameter,
North Star 8,000,000 miles in diameter
Betelguese 43,000,000 miles in diameter.

Help the student groups develop illustrated presentations of the characteristics of stars using artwork, models, graphs, or overhead transparencies. They should be creative in illustrating each of the characteristics. After the presentations, students' ideas about stars should be challenged.

Time for Reflection: What Do You Think?
Student Interview on Earth and Space Science

Assess and discuss the prior knowledge of a student in one of the five earth and space science areas described above. In advance, set up a schedule with a classroom teacher that will not interfere with normal class activities. Take notes during the interview. Later, complete a reflective journal entry for the student. Discuss the results with the teacher and observe the student in daily activities to see if the student's thinking fits your conclusions.

Step 1. Select a discrepant event, phenomenon, or confrontational situation related to a physical science concept or generalization. Use the physical science alternative conceptions and activities above as an example of the format to be used or construct one using a similar format. Consider the probable prior knowledge of this student when planning this activity. Gather the demonstration materials or draw the phenomenon or situation.

Complete Steps 2 to 7 as described in the Time for Reflection: What Do You Think? - Student Interview on Heat in Chapter 13.

To complete this activity, include a title page and label the parts of the assignment indicated below.

1) A description of the concept or generalization and the demonstration materials, or a drawing of the phenomenon or situation.
2) A script of the key question and possible follow-up responses you will make to your students.
3) Write up the interview events as they occurred in reflective journal form. Identify the student by first name only.
4) Write your conclusion and a prescription in a short typed paper. Consider the following questions: What does the student believe (prior knowledge) about the concept or event? How does this belief relate to the scientific view? What have you learned about this student? How would you start a lesson for this student in this science area?

Examples of Learning Cycles Teaching Earth and Space Science Concepts

The following learning cycle lessons challenge students' conceptions of an earth and space science event with a more appropriate scientific explanation. Note the connection of each learning cycle phase to the student alternative conceptions addressed in the lesson.

<u>A Learning Cycle Involving Alternative Conceptions About The Earth: Its Oceans</u>

<u>Alternative Conceptions Addressed by the Lesson Plan:</u>

6. *When water evaporates, it ceases to exist.*
7. *When water evaporates, it turns into another visible kind of thing like steam or fog*.

<u>Lesson Goal</u>: To allow students to investigate, develop inferences, and differentiate between different elements of the water cycle.

<u>Grade Level</u>: Grade 2 or 3

<u>Prerequisites</u>: Can measure time intervals of a whole minute. Has experienced activities investigating the properties of matter and the phases of matter -- solid, liquid, and gas.

<u>Exploration:</u>

<u>Objective</u>: Students will investigate the observable characteristics of evaporation and condensation over specific time periods.

<u>Materials</u>: For each group: a paper plate, a piece of construction paper, a sponge, a

styrofoam cup, a jar with a lid, a small glass, water, potting soil with a spoon for dipping it out of its container, nine ice cubes, container for the ice cubes

Procedure:

A. Form groups of three students: materials manager, observer, and recorder.

B. Have the materials managers go to the equipment station and pick up the following: a plate, sponge, piece of construction paper, styrofoam cup which they half fill with soil, jar with a lid and small glass which they fill one half full of water.

C. While the group's materials managers are getting the equipment, ask the other members to make a matrix with six boxes on a piece of paper. The boxes should be labeled as follows: plate, sponge, construction paper, cup with soil, jar with lid, and small glass with water.

D. Ask the materials managers to go to the ice cube station and put nine ice cubes in a container. When they return to their group, the other students place the ice cubes as follows: put one ice cube on a plate, a second on a sponge, a third on a piece of construction paper, a fourth on top of potting soil in a styrofoam cup, a fifth in a jar with a lid, and four cubes in a small glass of water.

E. Ask each student group to illustrate and describe their observations as they respond to the following questions on the matrix sheet: What is happening to each of the ice cubes? What happens to the water dripping from the ice cubes? Where did the water go?

F. Ask the students to examine their ice cubes one hour later and to respond to each of the questions again.

Evaluation: Collect the students' observations from the exploration. Evaluate them considering completeness and specificity of the observations drawn or described. Evaluate group skills by assessing whether all participated equally in the activity and whether individuals offered help and explained ideas or instructions to others in the group.

Invention:

Objective: Students will develop inferences about recurring events as related to evaporation, condensation, and precipitation in the water cycle.

Materials: For each group: one styrofoam cup of hot water, one glass of cold water with an ice cube in it, one copy of Figure 15-9, drawing paper and materials, a mirror cooled with ice cubes plus one cold mirror for the teacher.

Procedure:

A. Ask students to report the results of their exploration activity to the whole class. During the reports, highlight statements made by students that relate to evaporation and condensation. Introduce and define the terms at this time using concrete examples from the students' observations. Demonstrate condensation by blowing across a cold mirror and noticing the haze. Give the students cold mirrors and challenge them to do this also.

B. Discuss the three states of matter that water is found in: solid, liquid, and gas. Water can change from one form to another. While in any one form, it can be moved to another location.

C. Have students return to their groups. To illustrate the forms of water and the water cycle, give each group a styrofoam cup of hot water. Meanwhile, ask the materials manager to obtain a paper cup of very cold water with an ice cube in it from a materials station. Ask the observers in each group to hold the glass of cold water just above the hot water and make observations. Ask students to discuss what they see and to record and illustrate their observations.

D. Select a few groups to report their observations to the whole class. They should be able to report the effects of water condensing on the cold glass and dripping back into the glass of cold water. Tell the students that the dripping water is similar to rain. As a result of condensation in nature, precipitation occurs. Precipitation can be in the form of rain (liquid), snow, sleet, or hail (solid). Condensation in nature can be in the form of dew, frost, or fog. Evaporation can occur from rain when it hits the ground and "dries up," fog when it "disappears" or evaporates, dew on grass when it "disappears," and from lakes, streams and oceans.

E. Challenge the students to observe all three forms of water: gas, liquid, and solid. They cannot observe the gas because water vapor is invisible. We can tell its presence, however, because it condenses on cold glass or metal when the gas brushes against it. Sometimes, we see fog or "steam" around our cup or outside (e.g. in clouds). These are not examples of water as a gas. But, they are examples of water vapor condensing into liquid droplets you can see.

F. Ask the students to illustrate the water cycle where water changes from one form or phase and returns to the original phase again. The students should use their observations of the hot cup of water and the cold glass of water for the illustration. They should use arrows to show the various stages of the water cycle. Ask one group to discuss their drawings with the class. Discuss the cyclic nature of the water cycle: water rises, evaporates from the cup, travels to the glass, condenses on the glass, and drops back into the hot water where it can evaporate again. Although this can happen repeatedly, energy (hot water) must be present to cause water to evaporate. Show the students Figure 15-10 in a transparency.

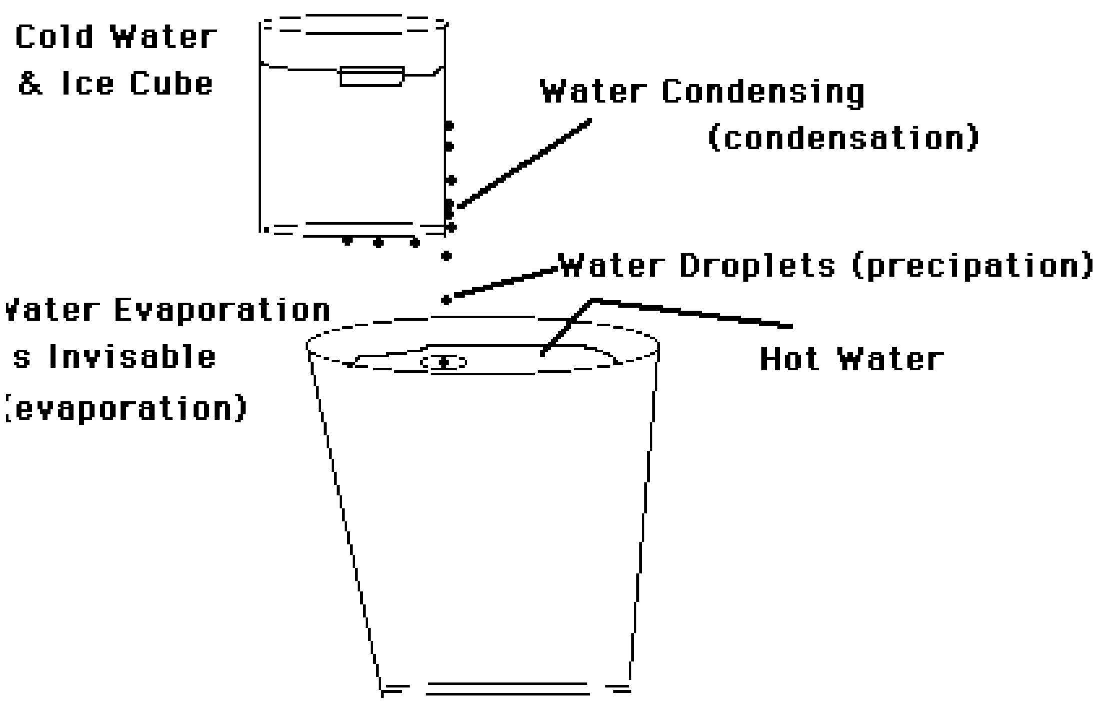

Figure 15-9: A cup and glass water cycle.

G. Provide every group with a sheet of paper and marking pens and ask them to illustrate a water cycle that answers this question: Where does rain that falls on land come from? Ask students to include a large lake and a flat land area in their drawings. When they have finished, ask two of the groups to present their illustration to the class. Then, give a copy of Figure 15-10 to each group. Have them compare this drawing with their drawing. Finally, ask one of the groups to explain Figure 15-10. See also Figure 15-11 providing sample answers.

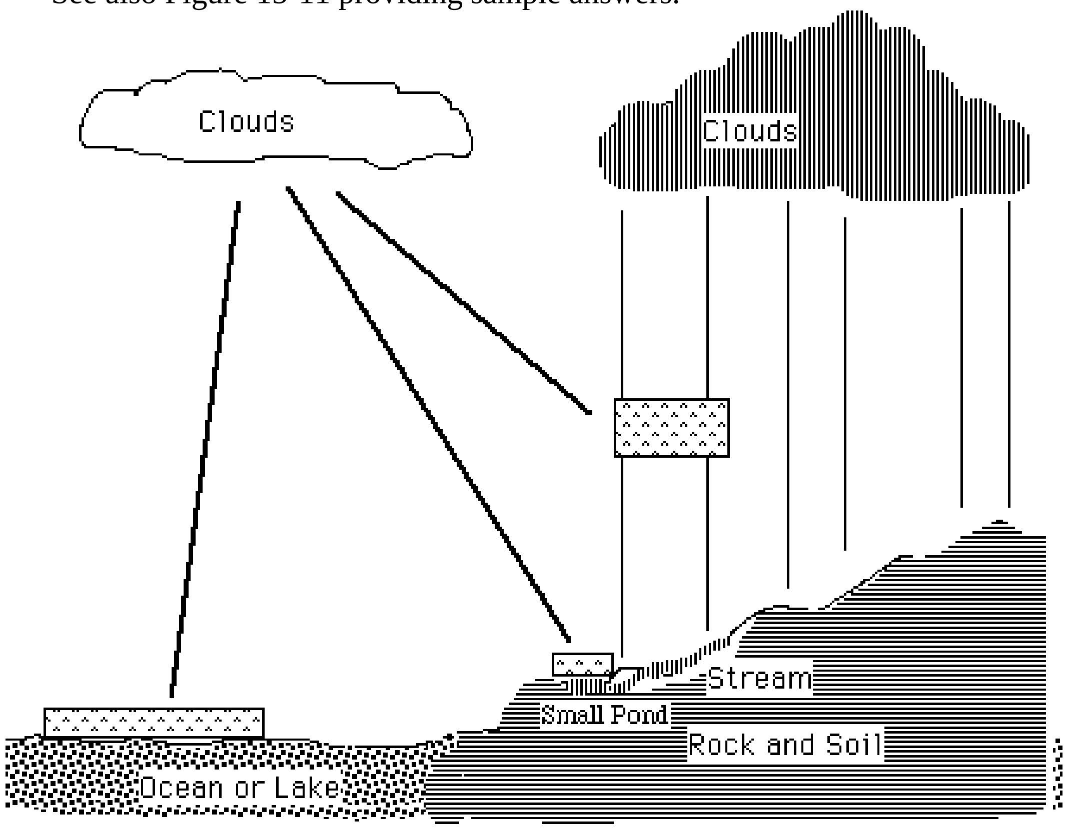

Figure 15-10: A water cycle out-of-doors. Describe what is happening.

H. Closure: The discussion leads students to draw the conclusions that the water cycle is a never-ending sequence of events. Water is never used up and never disappears as matter. Water can change form and move to another location where it may change form again, possibly into rain.

Evaluation: Collect the water cycle drawings and descriptions from each student. Evaluate the completeness and accuracy of each drawing. Evaluate group skills by assessing whether the groups review what to do before starting.

Expansion:

Objective: Students will apply the concept of the water cycle to recurring events involving evaporation, condensation, and precipitation.

Materials: For each group: three colors of construction paper, scissors, glue, one gallon-size baggie, one cup of potting soil colored with blue food, coloring dyed water.

Procedure:

A. Ask each group to cut out one-inch strips of pastel-colored construction paper. There should be three strips per student in each group. Have each student in the group write one term -- "evaporation," "condensation," and "precipitation"-- on each strip. Have each student glue the strips together to make a paper chain illustrating the water cycle. All students in the group should connect their separate chains to form a continuous, circular chain of water cycles. This helps illustrate the idea that water cycles have no beginning or end but recur over and over again. Ask the students to describe what their chain means.

B. In front of the class, have a student prepare one pound of potting soil by adding two cups of water with blue food dye in it. Have the materials manager from each group come up and collect a small styrofoam cup of soil and a one gallon sized zip-closing baggie. Ask the other members of the group to put the soil in the baggie and zip it tightly closed. Ask the students to predict what might happen if their baggie were left in the sun or on their desk overnight. Have students put their baggies near a window with sunshine, if possible. Periodically, during the day and on the next day, ask them to check their predictions by making observations of the baggie. When they make observations, ask them to answer the following questions: What do they observe? What happened to the water in the soil? Where did the water go? How did the water get from the soil to the top or roof of the bag? What color is the water that is condensed on the top of the bag?

C. Briefly summarize the main points and sequence of activities during the lesson.

Evaluation: Ask students to draw the water cycle occurring in the baggie. Collect the water cycle drawings and evaluate their completeness and accuracy.

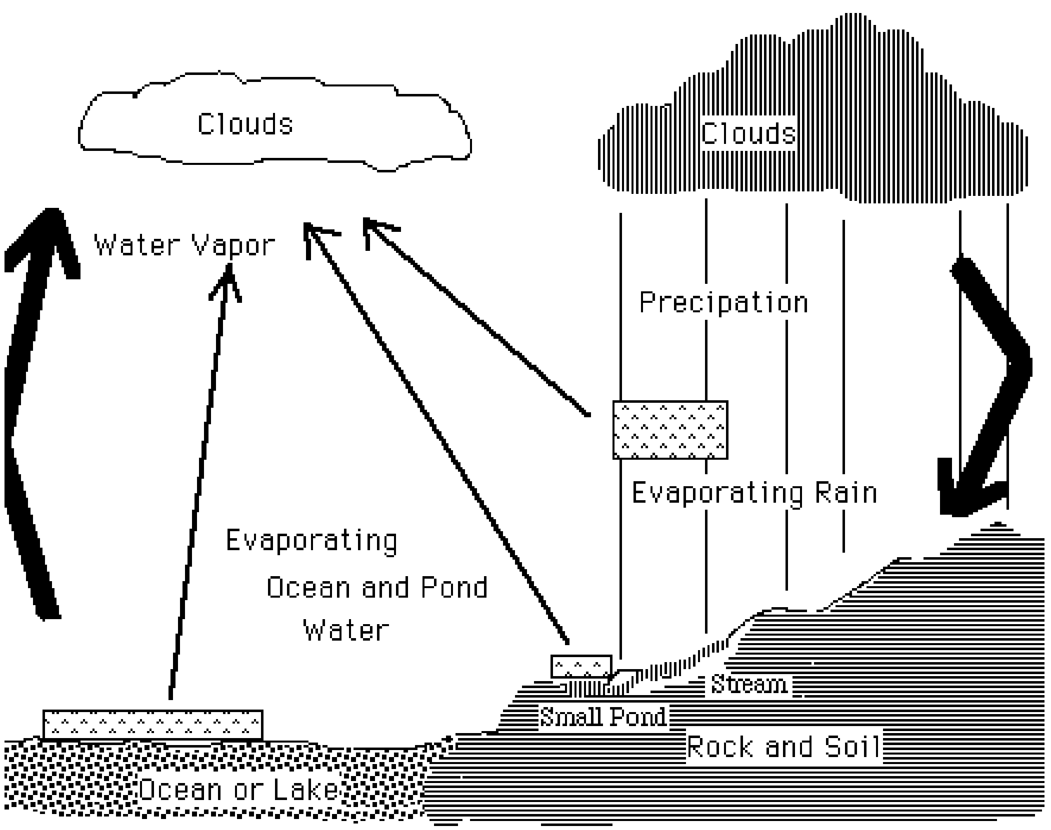

Figure 15-11: A water cycle out of doors. A sample explanation.

Additional activities and information in earth and space science lessons should relate to the nature of science (chapter 1) and the people who participated in creating it and work in the field today. Some examples of people who contributed significantly to the earth and space sciences but have been underrepresented in the mass media are listed in Table 15-3 along with their major contributions. Additional information can be found in library references such as an encyclopedia. The books Women in Science: Antiquity through the Nineteenth Century by M. B. Ogilvie (1986) and Random House Webster's Dictionary of Scientists by Jenkins-Jones (1997) are examples of resources. An Expansion activity to add to most earth and space science lessons would be to read a paragraph to determine the skills involved in the contribution of a related scientist or to interview a member of the community who uses skills and knowledge from the earth and space sciences in their daily work. The local soil conservation specialist in the community is an example of one such individual whom it may be possible to interview. Ask older students create research reports and short plays on the contributions of these underrepresented scientists.

Scientists are Diverse!

Some Who Have Contributed to Our Knowledge of Earth and Space Science

---

Florence Bascom

A female scientist in the USA studying optical crystallography.

Hisashi Kuno

A Japanese male scientist studying magma.

Matuyama Motonori

A Japanese male scientist studying magnetic field reversals of the Earth.

Mela Pomponius

A male studying climatic regions and doing early geographical work in Spain.

Doris Reynolds

An Englishwoman who studied how granite formed.

Shen Kua

A Chinese male who discovered the magnetic compass.

Table 15-3: Underrepresented scientists who have made significant contributions in the earth and space sciences.

A Practice Activity

In the fifth grade earth and space science lesson plan below on the topic of soil, do the following: a) identify possible alternative conceptions a student could bring to the lesson and, if available, interview a few children, b) develop key questions the teacher could use to guide student actions to create a confrontation to students thinking during the Exploration. Use the list of Examples of Alternative Conceptions About Geology described above as a starting point to identify the possible alternative conceptions.

Lesson Plan

A Learning Cycle Involving Alternative Conceptions About Geology

Lesson Goal: To allow students to investigate, develop inferences, and differentiate between different types of soil.
Grade Level: Grades 3 to 5
Prerequisites: Has experienced activities investigating the properties of matter and the phases of matter: solid, liquid, and gas. Has been involved in a lesson on erosion.

Exploration:

Objective: The students will investigate the observable characteristics of different types of soil.

Materials: For each group: a cup of water, drawing paper, newspaper or paper towels to cover their desks, four sandwich or quart-sized zipper type plastic bags, samples of four different types of soil, magnifying lens, two small limestone rocks (usually found along roadsides and in gravel driveways), two small sandstone rocks (usually found in roadside rock outcrops or used as garden rocks), one 30 centimeter ruler.

Procedure:

A. Ask each student to draw a picture of a field with bare soil that a farmer just plowed. Ask them to describe, in writing, the soil that is in the field. Then, ask students to describe the soil that is underneath, down deep. When the descriptions and drawings are complete, ask the students to form groups of four and share their descriptions and drawings with each other.

B. The students help prepare the next activity. Take them out on a short field trip. Give each group four sandwich or quart-sized zipper type plastic bags. Take the students to different parts of the school grounds to collect different types of soil. Map out the field trips beforehand to note where different soils are located. Check for sand or gravel, mulch around bushes and trees, clay soil on the playground and top soil in grassy areas. If many different soils cannot be found, the teacher should provide a small bag of sand, clay or potting soil from local soils (or purchased at a discount store such as Wal-Mart) to add to the diversity of soils the students will collect.

C. Back in the classroom, the groups begin working in the following roles: a materials manager, two observers, and a recorder. The materials managers go to the equipment station and pick up the following: a magnifying lens, old newspapers or paper towels to lay on top of desks to keep them clean, two roadside or driveway limestone rocks and two small sandstone rocks (or purchased in bags at a discount store such as K-Mart).

D. While the materials manager is getting the equipment, the other team members make a matrix with four boxes on a piece of paper. Each box is labeled with one of the types of soil available such as potting soil, humus, sand, clay, gravelly soil and topsoil.

E. Have the students look at the soil in small piles spread out thinly on a sheet of paper and dampened using a little water from a cup. They should use all of their senses except taste when making their observations. The students examine the rocks using a magnifying lens and try to measure grain size.

F. Confront the students with the observation that humus and potting soil are different from clay and sand.

G. Ask each group to illustrate and describe their observations as they respond to the key questions.

Evaluation: Collect students' observations from the exploration. Evaluate them considering completeness and specificity of observations drawn or described in response to the key questions. Group skills are addressed by observing whether the group forms quickly and stays together while it is working.

Invention:

Objective: Students will make inferences about soil types and where they are found.

Materials: For each group: two limestone rocks and two sandstone rocks from the exploration activity, two sandstone rocks, two pieces of black construction paper, one magnifying lens, one 30 centimeter ruler, one cup of water, eyedropper

Procedure:

A. Ask the student groups to report their findings from the exploration. Help the students focus on observations made with all their senses such as coarseness of grains of soil, the shape of the grains, and the evidence that some soils become wet when water is added while others do not.

B. Ask student groups to take their limestone pieces and hold them over a black sheet of construction paper. They should rub both rocks together until there is a thin coating of limestone dust on the paper. Label this paper "limestone soil." Next, take another sheet of black construction paper, pick up the two sandstone rocks and repeat the process. Label this paper "sandstone soil."

C. Ask students to gather together as much of the rock soils as possible in a pile on each sheet. Have them make observations of these piles and list similarities and differences. Measure the thickness of the soil layer (less than a millimeter). Next, add a few drops of water to each of the piles using an eyedropper. Ask them to compare the results. Then, add a few more drops of water to the piles. Are there different observations? Instruct each group to use the activity just described to come up with an inference about how soil on the earth forms, how fast different types of soil form, and the different types of soil that might exist.

D. Have a few groups present their ideas to the class. The teacher should add that it takes a long time for soil to form. In some places where the climate is moist and the temperature is hot, it takes thousands of years for a few centimeters (inches) of soil to form. In places where it is very cold or in dry desert conditions, it takes soil much longer to form.

Soil is formed in two ways. One is through weathering: rocks break down because other rocks or water rub or push against it. Soil is also formed through the chemical action of substances dissolved in the water. These are usually weak acids or substances formed from the air and plants. These acids dissolve the rock and carry it away in solution like sugar dissolved in water. The teacher should put an outline on the board describing how soil is made: 1) moving air or wind blow away pieces of rock, 2) rain and running water wear down rocks, 3) freezing water in cracks and ice breaks loose rocks, 4) plants and humans break apart rocks, and 5) chemicals dissolved in water decompose rocks. Some soil facts that can be discussed include: in the 1700's the soil in the USA was on average 23 cm. or nine inches deep. Today, the topsoil covering the USA is 15 cm. or six inches deep. We have lost one-third of our soil from wind and water erosion.

E. Closure. Soils are built up very slowly: it takes thousands of years for a few centimeters to be formed. Soils form through the wearing away of rocks either by rubbing or by chemical action. Depending on the type of rock that is weathered and the type of climate, different types of soil will form. Soils have different characteristics including the size of the particles that make them up and their ability to hold water.

Evaluation: Evaluate group reports based on their completeness, specificity, and evidence. Assess group skills at the discovery stations by observing whether all students in the group identify and classify substances and whether evidence is provided to support the ideas when given.

Expansion:

Objective: Students will make inferences about soil types and where they are found.

Materials: For each group: one large quart or liter jar with a screw-on lid (mayonnaise or canning jar), a measuring spoon, one cup of sand, one cup of potting soil, one cup of clay

Procedure:

A. Ask the materials manager from each group to go to the materials station and obtain one jar and one styrofoam cup each of sand, potting soil, and clay. The other group members should put all of the soils into the jar, tightly close the jar, and shake it up for about one minute. Then the group should go to a water source in the room and carefully put in enough water to fill the jar two-thirds full and put the jar's lid on tightly again. Then the jar should be shaken for about one minute.

B. The jar should be placed in the center of the group's work table and the contents allowed to settle. Students keep a journal noting the time and their observations and illustrations of their observations. This may take 15 to 20 minutes. The water may not be clear at the end of this time, but the soil will have settled into layers at the bottom of the jar. The groups should present their observations to the class.

C. The teacher should elaborate on students' observations, noting that soil is usually found in layers in areas undisturbed by people such as in forests or near streams. These layers can be seen when areas of soil are exposed in a hole or by a reeducate. There are usually four layers, or horizons, in an undisturbed soil profile. The thickness of each layer varies with location. Not all layers are present everywhere. The topmost layer has a lot of plant material. It looks darker and is usually composed of mostly plant material with a little soil mixed in. A good example is often found in the top layer of leaf litter soil in a forest (Figure 15-12). The second layer is still fairly dark since it contains some plant material. It is usually the soil that is called "topsoil." This is the soil generally seen in farmer's fields. It has many minerals and nutrients in it. The third soil layer is called the subsoil. It is lighter in color and does not have very much plant matter. The lowest layer is made up almost completely of large rocks and soil that has just broken off of rocks. This layer is on top of the solid rock below it. Beneath this layer is bedrock.

D. If time permits, have students visit a site on the school grounds where soil has not been disturbed and layering is visible. Check this out beforehand. One to three shovelfuls of soil are all that is needed. Ask students to dig a small hole down one half to one meter (16 to 36 inches). Ask them to draw the variations of color and composition of the soil under the surface. Have them make a comparison of the layers found here using the information on soil layers provided earlier.

E. Briefly summarize the main points and activities of the lesson.

Evaluation: Ask students to describe how soil characteristics vary with depth. Have them illustrate and describe these characteristics including the nature of the bedrock underneath. Evaluate their completeness and specificity.

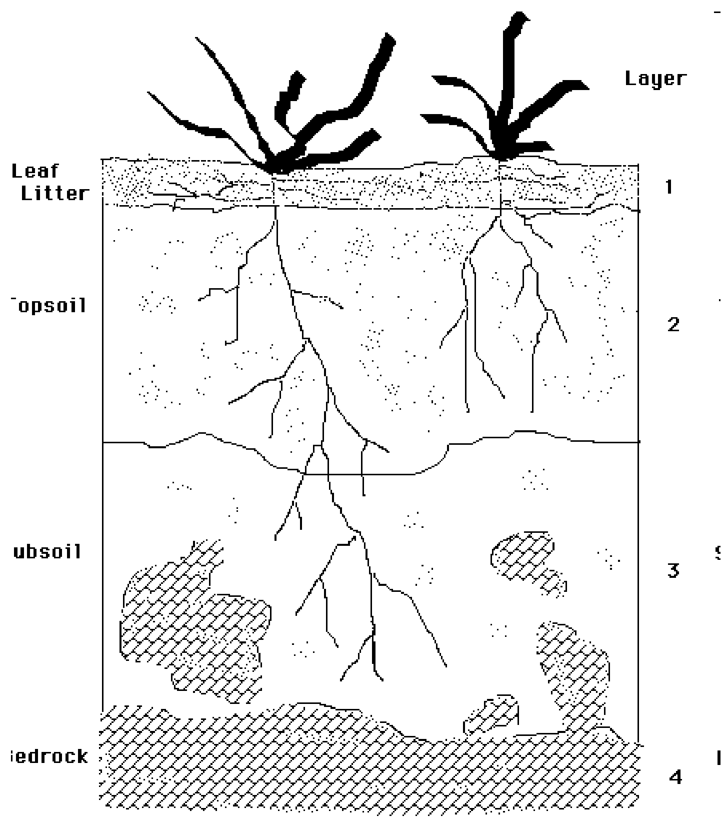

Figure 15-12: Undisturbed soil layers. Depth of each varies with location.

Compare your answers with those below.

A. The possible alternative conceptions a student might bring to class regarding soils include the following: 4. *Soil must always have been in its present form*. 5. *There is only one kind of soil*. 6. *All soil looks, feels, and smells the same*. 7. *Soil is the same on top as underneath, even in undisturbed soil in the forest*.

B. Key questions useful in guiding student actions during the Exploration, Section E, include the following. How many similarities and differences between the soil samples can you find? Describe how each soil feels. How can you draw or illustrate your observations based on what you hear, touch, and smell? For Section F key questions include, Where do these rocks come from? and What types of soils will these types of rocks produce?

Summary

Students, regardless of how much they read, rely on analogies they make based on familiar objects and events to understand and explain what they see in the classroom. Thus, students' common sense everyday knowledge can lead to alternative conceptions of science concepts. When teaching the earth and space sciences, purposeful observations and experiences of events are important and should be developed before analogies and models are used. Concepts and generalizations should be developed based on evidence from objects and events and in context with analogies and models whose limitations must be presented. The steps in accomplishing this process include a diagnosis and eliciting of student ideas through experiences, questioning, and demonstrations. This should be followed by a time for testing or challenging these ideas. Finally, scientific ideas supported by evidence should be experienced by students in order to replace a common sense view developed about the earth and space sciences.

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Some Useful Internet Web Sites to Explore

http://www.alsde.edu/cos/draft/draftcos.html
Alabama Courses of Study, state science standards, grades K-8
http://athena.wednet.edu/
Athena: Oceans, earth, weather, atmosphere, apace and astronomy, grades K-8
http://antwrp.gsfc.nasa.gov/apod/astropix.html
Astronomy Picture of the Day: Features a different image or photo of the universe each day., grades K-8
http://covis.atmos.uiuc.edu/guide/clouds/html/cloud.home.html
Cloud Catalog: Cloud formations, middle grades
http://medicine.wustl.edu/~kronkg/
Comets and Meteor Showers: Information and pictures of comets and meteors, middle grades
http://project2061.aaas.org/tools/benchol/bolframe.html
2061 Science Benchmarks Online
http://www.enc.org/
Eisenhower National Clearinghouse, resources include lessons, online publications, and services, grades K-8.
http://www.soest.hawaii.edu/SPACEGRANT/class_acts/
Exploring Planets in the Classroom, middle grades
http://pao.gsfc.nasa.gov/gsfc.html
Goddard Space Flight Center: Space-related lesson plans, grades K-8
http://www.jpl.nasa.gov/galileo/
Galileo: Bringing Jupiter to Earth: Lessons and activities on the spacecraft probe, scroll and select Online from Jupiter, middle grades
http://library.advanced/org/10568/
The Hitchhikers Guide to Model Rocketry: Designing first rockets, middle grades
http://www.stsci.edu/EPA/Pictures.html
Hubble Space Telescope Public Pictures, grades K-8
http://www.jpl.nasa.gov/
Jet Propulsion Laboratory: Lessons plans for earth and space science, grades K-8
http://groundhog.sprl.umich.edu/curriculum/
K-12 Weather Curriculum, grades K-8
http://onesky.engin.umich.edu/
Kids as Global Scientists Weather Curriculum, middle grades
http://www.lerc.nasa.gov/Other_Groups/K-12/windtunnel.html
LeRC K-12 Wind Tunnel Home Page: Aeronautics/Rocket Activities, middle grades
http://www.ucmp.berkeley.edu/fosrec/fosrec.html
Learning from the Fossil Record: Paleontology activities, grades K-8
http://www.lerc.nasa.gov/Other_Groups/K-12/TRC/TRCactivities.html
Lewis Teacher Resource Center: Aeronautics, middle grades
http://www2.ucsc.edu/mlrg/proc4abstracts.html
From Misconceptions to Constructed Understanding: Proceedings of conference in Ithaca NY
http://www.narst.org/
National Association for Research in Science Teaching
http://www.nsta.org/
National Science Teacher's Association, resources for improving the teaching of science,

grades K-8

http://www.nap.edu/readingroom/books/nses/html/

National Science Education Standards

http://www.nasa.gov/

National Aeronautics and Space Administration: Includes links to 12 NASA centers, middle grades

http://nssdc.gsfc.nasa.gov/photo_gallery/

NSSDC Photo Gallery: Photos of planetary, astronomical, and related objects, middle grades

http://www.nasm.edu/

National Air and Space Museum: Aviation and Space Science, grades K-8

http://www.lam.mus.ca.us/lacmnh

Natural History Museum of Los Angeles County, grades K-8

http://spacelink.msfc.nasa.gov/html/Instructional.Materials.html

NASA SpaceLink Instructional Materials, space-related lesson plans and activities, grades K-8

http://www.ou.edu/tornado/CAPS.WWW/teacher.html

Rain or Shine: Explorations in Meteorology, grades K-8

http://www.seti-inst.edu/Welcome-page.html

Search for Extraterrestrial Intelligence Institute: Life in the Universe Curriculum Project, middle grades

http://www.cea.berkeley.edu/Education/sol/sol_toolkits.html

Science Online: Science Resource Toolkit, middlegGrades

http://water.dnr.state.sc.us/climate/sercc/education/saer/southern_aer.html

Southern AER: Southeast Regional Climate Center interactive weather activities, middle grades

http://spacelink.nasa.gov/.index.html

SpaceLink, grades K-8

http://heasarc.gsfc.nasa.gov/docs/StarChild/StarChild.html

StarChild: Astronomy resource, grades K-8

http://www.seds.org/

Students for the Exploration and Development of Space, middle grades

http://w3.cea.berkeley.edu/Education/lessons/lessons_teacherdeveloped.html

Teacher-Developed Earth and Space Science Lessons and Classroom Activities: Weather, satellites, auroras, and earthquakes, grades 4-8

http://www.usgs.gov/education/

U.S. Geological Survey's Learning Web, grades K-8

http://bang.lanl.gov/solarsys/

Views of the Solar System, middle grades

http://volcano.und.nodak.edu/

Volcano World: Volcano-related lessons, middle grades

Http://www.ncsa.uiuc.edu/edu/RSE/RSEred/WeatherHome.html

Weather Here and There, grades 4-6

http://faldo.atmos/uiuc.edu/w_unit/weather.html

The Weather Unit: Integrates the study of weather into all curricular areas., grades 2-4

http://sln.fi.edu/tfi/units/energy/wind.html

Wind: Our Fierce Friend: The science of wind energy, grades 4-6