beetles
Science and Teaching for Field Instructors

Student Activity Guide

Double Take

Based only on what we see when we watch stars in the sky, it's easy to believe that the stars revolve around a stationary Earth, a common misconception among children. Although many students have at least heard that the Earth spins, they may not have thought about how this affects how we see stars, planets and the Moon. In this activity, students find evidence of the Earth's spinning through observing the apparent movement of stars. They use outstretched arms to measure the distance between a star and an object at the horizon. Later, they return to the same spot, re-measure, and notice that the star is in a different position, and try to explain this movement. Finally, the instructor shares the accepted scientific explanation for the phenomenon.

Students will...

- **Observe that the stars (and Moon, if available) appear to move across the night sky relative to Earth**
- **Recognize that stars (including the Sun) moving across the sky are evidence of the Earth spinning**
- **Notice that the stars and our Moon move across the sky differently.**

Grade Level:
Grades 3-8. Adaptable for younger or older students.

Timing:
about 20 minutes total, split into two 10 minute chunks at beginning and end of nighttime field experience

Related Activities:
Night Hike Scavenger Hunt, How Big & How Far, Moon Balls

Materials:
No materials needed

Tips:
To ensure a successful experience, review the teaching tips found on page 2 and throughout this guide.

Setting:
To complete this activity, you need at least a mostly clear night sky. Choose a recognizable spot where the group can observe the sky and return at least 30 min. later.

NEXT GENERATION SCIENCE STANDARDS

FEATURED PRACTICE	FEATURED CROSSCUTTING CONCEPT	DISCIPLINARY CORE IDEAS
Constructing Explanations	Cause and Effect	Earth and the Solar System

For additional information about NGSS, go to page 8 of this guide.

THE LAWRENCE HALL OF SCIENCE
UNIVERSITY OF CALIFORNIA, BERKELEY

Double Take

ACTIVITY OVERVIEW

Double Take	Learning Cycle Stages	Estimated Time
Measuring an Object		5-10 mins.
Returning to Measure and Discussing Results		5-10 mins.
Wrapping Up		3 mins.
TOTAL		~20 minutes

TEACHING TIPS

Field Card. On page 11 of this guide is a pocket-sized version of this lesson that you can use in the field.

Read the Instructor Support Section. Beginning on page 6, you'll find more information about pedagogy, student misconceptions, science background, and standards.

Activity Connections. This activity can be used to support *Night Hike Scavenger Hunt*, in which students search for things at night (including evidence of a spinning Earth). This activity also connects to *How Big & How Far*, an activity about scale of night sky objects, and *Moon Balls*, an activity in which students use a model to explain the phases of the Moon.

Pay attention to students' physical needs. If many students in your group have different explanations for what they've observed, this discussion could go on for a while. In the context of a night field experience in which it's dark, and often cold, don't keep students standing still for too long. Allow a few students to share alternate explanations and their reasoning, but move on if students seem to be getting cold from standing in one place for too long.

Measuring an Object

1. **Gather students in a spot you'll be able to recognize later.** Gather students in a cluster or circle in a location they'll be able to return to later in the night hike. Choose a spot that will be easy to find in the dark when you return, like a circle of seats, a stump, etc.

2. **Explain that you'll be comparing where stars are now with where they are later in the hike to see if/how they move.**

3. **Together, choose a recognizable object in the sky and a recognizable object on the horizon.** Find a fairly easily identifiable celestial object (like a bright star, a small group of stars or a planet) near a recognizable landmark at the horizon, e.g. "See those 3 stars that look like a triangle just to the right of that tall tree?"

4. **Tell students to stretch an arm out in front of them, and use fists/fingers to measure the distance between the sky object and the landmark you chose.** Ask students to stretch an arm with a fist out as far as possible toward the star/constellation/planet, and to measure the number of fists and fingers between the object in the sky and your group's chosen horizon landmark. Show students how to use a fist (and/or fingers) as a unit of measurement between the object and the landmark. For example, "I measured that the bright star is 1 fist and 2 fingers up and to the right of that tree."

5. **Explain that they need to memorize their measurement to compare with their measurement later.** Explain that they'll return to this same spot to measure again later on, so they need to memorize their measurement now so they can compare it with their measurement later.

6. **Ask pairs of students to Turn & Talk to predict if sky objects will be in the same position when they return, and to discuss their reasoning.** Tell pairs to quietly Turn & Talk to discuss with another person the following questions:
   - *When we come back here later on tonight, do you think the object you chose will be in the same position, or do you think it will have moved?*
   - *If you think it will move, where do you think it will move to?*

7. **Ask a few students to share their ideas with the whole group.**

Returning to Measure and Discuss Results

1. **At least 30 minutes later, return to the same spot and ask students to re-measure the distance between the same objects, and report their results.** Gather your students in the same spot and help them find the same sky object(s) they chose and the identifiable object at the horizon that they chose before. Tell students to use their fingers and fist on an outstretched arm, just like they did before, to measure the distance between the two objects, and to compare this with the distance they measured earlier. Then, ask students to share their results with the group. [they will likely agree that the distance is different]

TEACHING NOTES

The whole group needs to measure the distance between the same two objects. Otherwise, students may become confused later on as they try to discuss their observations with each other.

Should you measure the Moon too? Probably not. The Moon moves differently from the stars and planets, because it actually is orbiting Earth. But to notice the special motion of the moon you need to measure its position against the stars rather than against the horizon, and even then, it takes more than a half hour to observe a change, unless you are very careful. But it is worthwhile for students to discuss how the movement of the Moon is different from that of the stars and planets.

Informal assessment opportunity. Turn & Talk is a great opportunity to listen in on student discussions to find out if they are tending to believe that the stars spin around the Earth or that the Earth is spinning.

Discussing with quiet voices. Keeping voices low, and sometimes silent on a night hike allows students to notice more with their senses, and also can add a "magical" feel. It's also considerate of other groups who may be night-hiking nearby. During discussions, instruct students to speak in whispers or quiet voices.

2. **Ask pairs to discuss possible explanations for what happened; to explain the cause for the effect they observed.** Ask why they think this happened. Tell them to discuss with someone nearby to come up with an explanation for their results. Tell them they just observed an effect (the stars appeared to have moved), and now they're attempting to explain the cause of that effect.
   - *What moved, and how could that have happened? What is a possible explanation for why the object [star, planet] isn't in the same position as before, and what's your evidence?*
3. **Ask students to share their ideas with the whole group.** Ask a few students to share out their explanations. When a student shares an explanation, ask other students whether they agree or disagree with the explanation, and why. Ask if any students came up with a different explanation, and why. If students agree or disagree with one another, give them a chance to share their reasoning- but move on before students get cold or run out of steam for discussion.
4. **Explain that for thousands of years, scientists made observations and tried to find the best possible explanation for what students just observed, and for a long time many thought the stars revolved around Earth.**
5. **Explain that modern science, based on many scientific observations (that include things students couldn't see tonight), has found all evidence supports the explanation that the Earth spins, (and not the explanation that the Sun and stars orbit Earth).** Explain to students that scientists have been able to make more observations and measurements than the students could have made tonight, and that those observations are evidence that support the explanation that the Earth spins, and NOT that the Sun or stars orbit the Earth.

Wrapping Up

1. **Explain how what they have been doing reflects scientific thinking.**
   - *Science is about coming up with the most accurate explanations about the natural world based on all available evidence.*
   - *Sometimes this means science replaces an explanation with a more accurate one, like when the explanation that stars revolve around Earth was replaced with the more accurate explanation of Earth spinning.*
   - *As they discussed explanations based on evidence and reasoning, they were being scientific.*
   - *It's also a sign of scientific thinking if you changed your mind based on evidence and reasoning.*
2. **Ask students to reflect on how their ideas may have changed and what made their ideas change.** Point out that if anyone changed their mind based on new reasoning or evidence from others, they are thinking like scientists. Of course they can still be thinking like scientists if they didn't change their mind, but it's good to celebrate students who change their minds based on evidence and reasoning.

TEACHING NOTES

When student results disagree. When a group of students reports data, it's common for one or more members to have results that differ from others. It's easy for students to mis-measure or misremember what they measured before. Tell them it's easy to make mistakes, and that's why scientists check their work as many times as they can. One way to get more accurate results is to have many groups measure the same thing, which is what they just did. Tell students that for now you're going to work with the majority's results, because those results are supported by more

How will the object have moved? The way the object you are measuring moves depends on where in the sky it is. Stars in the west will be closer to the horizon than they were earlier. If you measured an object very near the western horizon, it may have set all together. Objects observed in the East will appear higher above the horizon. Objects may look like they have shifted (most often to the right in the northern hemisphere) especially near the northern or southern horizon. The only star that will be in in the same spot (almost) is Polaris, also called the North Star.

Thinking about cause and effect. If you point out to students that they are using the scientific thinking tool (cross-cutting concept) of cause and effect, they get the opportunity to recognize the idea of cause and effect as an important way of looking at the natural world. To help them develop a stronger understanding of cause and effect, help them apply it in other activities and contexts.

Discussing movement of the Moon. If you think your students will be into it, you might want to ask them to discuss how the Moon moves in relation to Earth. Although it's harder for students to measure and observe the difference from how the stars move, the Moon does move differently because it actually is orbiting Earth.

3. **Encourage students to continue to observe the sky and notice evidence of Earth spinning.** Encourage students to keep making observations of the sky (without looking directly at the Sun) and keep noticing how stars, the Moon and the Sun appear to move across the sky because of the spinning of the Earth.

4. **[optional] Check off "Evidence of Spinning Earth" if you are also doing the Night Hike Scavenger Hunt.** If you are also doing the Night Hike Scavenger Hunt activity, some students will probably point out that this is evidence of a spinning Earth, one of the scavenger hunt items. They might also point out that since the Moon is orbiting Earth, it's a natural satellite, another scavenger hunt item. You may need to point this one out for them though.

TEACHING NOTES

Shifting students' understandings gradually. Careful assessments of students show that it's generally unrealistic to get an entire class to change their ideas about something significant in the course of one learning experience. Even when all students in a class are able to answer a question about a concept correctly on a test, deeper assessments (such as one-on-one interviews) often show that some students know how to give an expected answer but continue to harbor a misconception. Generally, if you can get a group of students' ideas to move in the direction of more accurate explanations, you're doing well. Hopefully students in your group will walk away with better understandings about the spinning Earth. At the very least, all students in the group will have had opportunities to make careful observations, to discuss ideas with peers, and to notice that objects in the sky do not remain in one position.

TEACHING NOTES

Instructor Support

Teaching Knowledge:

Sharing ideas in pairs first. It's important, whenever possible, for students to share their predictions and ideas in pairs before sharing them with the whole group. It takes confidence, and guts to share ideas with a group, especially if you're uncertain about your ideas. When talking in the lower stress situation of a discussion with one other person, especially a peer, students get to try out ideas, and listen to their partner's ideas. Pair talk before whole group talk tends to lead to more participation in the whole group discussion, and also to more thoughtful responses. Students who do not feel comfortable sharing with the whole group also get a chance to talk with their partner.

Content Knowledge:

Evidence that the Earth is Spinning

From just making observations of the sky, it's easy to believe that the Earth is stationary, and the stars and planets revolve around it. If stars were revolving around the Earth, we might expect them to be moving at different speeds, but they all appear to move at the same pace, so this observation might support the explanation that it's the Earth that is spinning. Luckily, we have other ways to observe and give us evidence about what's going on, like observing the Earth spinning from spacecraft. But long before those kinds of observations were possible, science demonstrated evidence that the Earth spins.

The laws of physics tell us that when a pendulum swings it follows the same path back and forth. But if a pendulum is carefully set up, and swings on the surface of the Earth for several hours, you can observe that the pendulum is swinging across a different path than it originally followed. This apparent change of path is evidence of the Earth rotating underneath the pendulum. Leon Foucault demonstrated this phenomenon in 1851 using a device that is now known as the Foucault Pendulum.

This evidence of Earth spinning can be hard to understand without actually seeing the phenomenon, so you probably won't get much traction out of trying to explain this to students on a night hike. But it's good for you as an instructor to be aware of, so if a student brings up ideas about pendulums, you'll have an idea of what they're talking about. What you probably will want to share with students is that there is significant scientific evidence that supports the explanation that the Earth spins, and that those observations can't be made in the moment from where students are.

Stars

Every star is a sun. Our nearest star is the Sun. It's a medium-sized star, although it looks much larger than other stars/suns because it's much closer to us. Almost every star you can see with the naked eye is bigger than our Sun, but most stars are smaller than the Sun. How can that be? It's because we can't see many of the smaller stars without a telescope. We see way more of the bigger stars. Our Sun is ~8 light minutes away. The second nearest is ~4 light years away (Proxima Centauri). Traveling at 186,000 miles per second, it

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takes light ~4 years to travel to our second nearest star!

Moon

The Moon is a natural object that orbits Earth, so it's our natural satellite. It takes about 1 month to orbit Earth. It's ~1.5 light seconds from Earth (~240,000 miles).

Measuring Time with the Sun

You can measure time using our nearest star (the Sun) with an outstretched arm: one finger width = 15 minutes. One fist = 1 hour. So if the Sun is one fist away from the horizon, then it's about 1 hour until sunset (but not at high latitudes, or at lower latitudes in the Southern hemisphere). But when doing this it's important to remember not to look directly at the Sun, because it can damage your eyes. This doesn't work with most other stars, by the way.

Handy Measurements

Both "digit" and "palm" are units of measurements once used in ancient societies including Egypt and Mesopotamia. While these units of measurements are now scientifically obsolete, amateur astronomers still use fingers and hands to approximate degrees and distances between objects the night sky. A pinkie held out at arms length is approximately one degree wide, while three middle fingers held out at arms lengths measures approximately five degrees.

Common Relevant Misconceptions

The Earth, Sun, Moon and stars are the space objects we can most easily observe, with the Earth and Sun playing particularly important roles in our lives. But even daily observations of these space objects from Earth can easily lead to misconceptions about how they interact. For millions of years, people have observed the Sun and stars rise in the east and set in the west, and until relatively recently, many have explained this using a model in which the Sun and stars revolve around the Earth. It's easy to understand how many children today come up with Earth-centered explanations for what they see that are very similar to explanations many smart thinkers have come up with over millenia. Eventually, Copernicus came up with evidence and an explanation that involved the Earth orbiting the Sun. Although he encountered a lot of opposition to his ideas, since then all evidence has supported this explanation.

- **Misconception:** The Sun and stars go around the Earth every day.
- **Misconception:** The Sun moves up and down.
- **Misconception:** The Earth spins, with the Sun and Moon orbiting Earth on opposite sides from each other.
- **Misconception:** The Earth and Moon both independently orbit the Sun.
- **Misconception:** The Sun and Moon appear and disappear "magically."

  More accurate information: The Sun and stars appear to rise and set because the Earth spins on its axis (a line that runs through the North Pole and South Pole). The spinning of the Earth causes night and day.

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Find the latest activities and information at http://beetlesproject.org.

The Earth orbits the Sun once every ~365 days, which marks one year. The Moon orbits Earth about once a month.

Connections to NGSS

BEETLES student activities are designed to provide opportunities for the "three-dimensional" learning that is called for in the NGSS. To experience three-dimensional learning, students need to engage in scientific practices to learn important science content (Disciplinary Core Ideas) and relate that content to the unifying themes in science (Crosscutting Concepts). In simple terms, students should be exploring and investigating rich phenomena, trying to figure out how the natural world works.

Double Take engages students in the practice of Constructing Explanations to build a foundation for understanding disciplinary core ideas related to Earth and the Solar System, and to relate those ideas to the crosscutting concept Cause and Effect.

Featured Science and Engineering Practices

Engaging students in Constructing Explanations. According to NRC's A Framework for K-12 Science Education, a major goal of science is to deepen human understanding of the world through making explanations about it, and students should develop their understanding of science concepts through making their own explanations about natural phenomena. In Double Take, students observe stellar objects shift in position then make possible explanations about what might have happened. For students to engage more deeply in this practice, it's important to ask students for alternate explanations for this phenomenon in the whole group, and to ask students to share the reasoning behind their thinking.

In order for students to fully engage in this practice, they need to consider how the practice of making explanations about the natural world connects to the nature of science and how scientists learn about the world. Be sure to share with students the idea that the explanation of the spinning Earth (and much of scientific knowledge) was built from observations of the natural world by scientists. Explain that scientists came up with possible explanations, discussed them "open-mindedly", and settled on the spinning Earth explanation because it was the best explanation based on all the available evidence.

Connections to Crosscutting Concepts

Learning science through the lens of Cause and Effect. When scientists make explanations for how or why something happens, they're thinking about the "big idea" of cause and effect. What we can observe of the natural world are the "effects" of many causes. In Double Take, students observe the shift in position of a stellar object relative to the horizon, which is an observable phenomenon (or "effect") caused by the Earth's rotation. Students apply the idea of cause and effect when they make a possible explanation for the phenomenon they observed. If students don't get the chance to consider how the idea of cause and effect connects to the explanations they are making, they miss the opportunity to recognize the idea of cause and effect as an important way of looking at the natural world. Students also might not realize

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that the idea of cause and effect also applies in other scenarios- like observing other types of phenomena and making possible explanations for processes at work anywhere. To help them develop a stronger understanding of cause and effect, help them apply it in other activities and contexts.

Featured Disciplinary Core Ideas

Building a foundation for understanding Disciplinary Core Ideas. The NGSS make it clear that students need multiple learning experiences to build their understanding of disciplinary core ideas. *Double Take* provides students with an opportunity to develop understanding of Earth and space science ideas relating to ESS1.B: Earth and the Solar System.

When students observe stars shift positions throughout an evening, discuss possible explanations for what happened, and then hear the accepted scientific explanation for the phenomenon, this can lead to better understanding of the idea that stars appear to move together across the sky because of Earth's rotation (ESS1.B). If students are able to observe the movement of the Moon and discuss the Moon's orbit, students will build some understanding of the idea that the orbits of the moon around the Earth and the rotation of the Earth cause observable patterns (ESS1.B).

As students discuss their explanations in pairs and in the whole group, listen to their ideas. It's common for students to have misconceptions about these concepts. One activity can generally neither shift every student's misconception nor fully develop students understanding of these complex ideas. You need additional activities for students to reach the point of fully understanding these concepts. Students can see the stars shift positions in the sky, but that is the only evidence they can actually observe. For students' learning experience to be complete, they would need to encounter additional evidence in other activities. During the course of this activity, it's enough to tell students that scientists have made lots of observations and that there is significant evidence that supports the Earth's rotation as the explanation for stars' apparent motion in the sky.

Performance Expectations to Work Towards

The NGSS represent complex knowledge and multi-faceted thinking abilities for students. No single activity can adequately prepare someone for an NGSS performance expectation. Performance expectations are examples of things students should be able to do after engaging in multiple learning experiences and long-term instructional units. They are descriptions of how students can demonstrate their understanding of important core ideas and science practices, as well as their ability to apply the crosscutting concepts. They do not represent a "curriculum" to be taught to students. Below is one performance expectations that this activity can help students work towards.

5-ESS1-2 Represent data in graphical displays to reveal patterns of daily changes in the length and direction of shadows, day and night, and the seasonal appearance of some stars in the night sky.

Activity Connections

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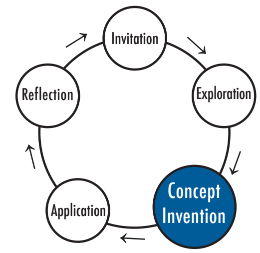

For other activities that connect to disciplinary core ideas within Earth and Space Sciences, try *Night Hike Scavenger Hunt*, *How Big & How Far*, and *Moon Balls*. To engage students in other activities that make use of the crosscutting concept "cause and effect," and making explanations from evidence, try *NSI: Nature Scene Investigators, Bark Beetles, Case of the Disappearing Log*, or *Structures & Behaviors*.

FIELD CARD

Cut out along outer lines and fold along the centerline. This makes a handy reference card that will fit in your pocket.

Double Take

Measuring an Object

1. Gather students in a spot you'll be able to recognize later.
2. Explain: you'll be comparing where stars are now with where they are later in the hike to see if/how they move.
3. Together, choose a recognizable object in the sky and a recognizable object on the horizon.
4. Explain: stretch an arm out in front of you, & use fists/fingers to measure the distance between the sky object & the landmark.
5. Explain: you need to memorize your measurement to compare with your measurement later.
6. Pairs Turn & Talk to predict if sky objects will be in the same position when they return, and to discuss their reasoning:

   ▶ *When we come back here later on tonight, do you think the object you chose will be in the same position, or do you think it will have moved?*

   ▶ *If you think it will move, where do you think it will move to?*
7. A few students share their ideas with the whole group.

Returning to Measure and Discuss Results

1. At least 30 minutes later, return to the same spot & ask students to remeasure the distance between the same objects, & report their results.
2. Pairs discuss possible explanations for what happened; to explain the cause for the effect they observed:

   ▶ *What moved, and how could that have happened? What is a possible explanation for why the object [star, planet] isn't in the same position as before, and what's your evidence?*
3. Students share their ideas with the whole group.
4. Explain:

   ▶ *For thousands of years, scientists made observations & tried to find the best possible explanation, and for a long time many thought the stars revolved around Earth.*

   ▶ *Modern science, based on scientific observations (including things you couldn't see tonight), has found all evidence supports the explanation that the Earth spins, (not that Sun & stars orbit Earth).*

Wrapping Up

1. Explain how what they have been doing reflects scientific thinking.

   ▶ *Science is about coming up with the most accurate explanations about the natural world based on all available evidence.*

   ▶ *Sometimes this means science replaces an explanation with a more accurate one, like when the explanation that stars revolve around Earth was replaced with the more accurate explanation of Earth spinning.*

   ▶ *As they discussed explanations based on evidence and reasoning, they were being scientific.*

   ▶ *It's also a sign of scientific thinking if you changed your mind based on evidence and reasoning.*
2. Ask students to reflect on how their ideas may have changed and what made them change.
3. Encourage students to continue to observe the sky and notice evidence of Earth spinning.
4. [optional] Check off "Evidence of Spinning Earth" if you are also doing the Night Hike Scavenger Hunt.

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ABOUT BEETLES™

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