Hello, Sun!

Purpose

In this Thread, we will examine the passage of time by watching the world change outside our classroom. The Sun will seem to move across the sky in a steady manner throughout the day. This will allow us to begin thinking about the movement of either the Sun or the Earth as well as the shape of the Earth so that the motions make sense. The National Science Education Standards call for students to become comfortable with objects' properties of size and movement, an example being the Sun. Students should learn that the Sun *appears* to move around the Earth, but in fact it is the Earth spinning around on its axis while the Sun remains stationary. This Investigation allows students to explore what the NSES refers to as "technological design". The vocabulary that can be integrated into this Thread are words such as Sun, Earth, day, night, spin, axis, arc, model, angle, sphere, and degree. For a new approach to learning some of these vocabulary words, visit **Word Lore**, an appendix dedicated to exploring the history of words pertaining to this curriculum.

Teacher Background

The easiest way to see time passing is with a clock, but what made us aware of passing time before clocks? The motion of the Sun is the key here, and most students do not know what that motion looks like.

You will need: chalk or wipe board and chalk/markers, easel, roll paper for easel, pencils, journals, crayons, adhesive yellow dots or BINGO markers.

The class will initially need a sunny day for this and will need to repeat measurements from the earliest time possible in the morning until school lets out in the afternoon, at one hour intervals. You will need to locate the direction South outside in the yard. In the classroom, you may want to spend several class periods spanned over a week thinking about the data you've collected. There are few tools required, so materials gathering for the investigation is minimal.

We know that we are a small planet shaped like a ball in orbit around a huge star 93 million miles away. This star we call the Sun, and it is an enormous ball of very hot gas. This star is so large, that even from this far away, its light can reach our planet. Sunlight is radiated from the Sun in all directions, and we are only a tiny planet in the way of a tiny bit of that sunlight. Therefore, we

get light from what appears in the sky as a small disc in a certain direction. If we were very close to the Sun, that orb would seem larger. Why do we feel warmth all over the land during the day? Well, that is because we have a lovely atmosphere to keep us warm like a blanket. Why then do we feel cold in the winter? That will be explored in a later Thread.

There is motion we can see on our world. In some respects, it appears that the Sun circles the Earth. Greek philosophers speculated about our world and its geometry and decided that it is the Earth which is turning on its own, making things appear to swing past it, outside of it. This is similar to being on a carousel and watching your family rush around you, even though it is you who are moving. To prepare ourselves to model the Sun, it would be good to first explore some alternative approaches to looking at the world around us. This requires thinking flexibly. Now would be a good time to introduce puzzles, riddles and optical illusions, to help us think about the importance of opening up our minds to different ways of seeing the same thing.

The movement of our Earth is very uniform, making the Sun rise, arc overhead, and set at the same speed everyday. This speed is our spin time, or day, of 24 hours. For students, the term "day" is more like the daylight time. Confusion between “days getting longer” but “days are always 24 hours long” can happen. Begin to refer to these times as daylight time and spin time, to ease communication among your students. In fact, perhaps we should consider inventing our own terminology for these two concepts in class.

As part of the ECT curriculum, we offer some lessons about how ancient and historical cultures used observations similar to those the students will make in the Threads. For *Hello, Sun!*, we’ve included background information and classroom activities in the Additional Resources section relating to how Scandinavians one thousand years ago used the Sun to tell time. We call it **Telling Time Without a Clock**. [Note: The Daymarks project is also relevant for the Thread called *This is a Stickup!*]

> "It is possible to store the mind with a million facts and still be entirely uneducated."
>
> —Alec Bourne, *A Doctor’s Creed*

Kindergarten through Second Grade

Developmental Issues

The purpose of this Thread for this age group is to emphasize the joys of wondering about our world and learning to look for change and patterns carefully. It introduces the skills of question asking, communicating ideas in speech and drawings, and manipulating objects. Students will learn about the Sun as our light and heat source and about our world as having a regular time pattern, which can be observed from the simple motion of the Sun.

This Thread is not intended to impose on students of this age the model of a turning spherical Earth past a distant steady Sun. Research shows that the average five year old is just learning how to envision images in his or her mind and to manipulate those images (for instance, thinking about how to walk to school and then reversing the route in one's mind). However, constructing images that require shifts that the child has never experienced, thinking about positions of objects in the future (beyond yesterday, today, tomorrow), and holding a dynamic model in one's head to reason about it, is challenging for students of this age.

It is important to realize that experience with models and analogies helps children learn to understand them. Teachers should not shy entirely away from presenting concepts that are slightly beyond the developmental level of their students, but that they should support the students' developing understanding with other paths to grasping the concept.

Inquiry Introduction

What is a day? Why is it that we know when a day has passed, or what time of the day it is? What are the things we look for to tell us about the time of day? Or when we are tired? Hungry? Cold? Are there things which always happen at a certain time of the day? Students may want to draw a day (allow yourself time to write a brief narration for each drawing based on their verbal description.) Are they thinking only about daylight time? Do any of them describe a day as more related to the spin time perspective?

Is there any way we can think of to see that a day is passing? Many students will suggest the clock. Tell them this is the modern way, but what about when people didn't have clocks or watches? Does anything change during the daytime which isn't a clock? If no one suggests the Sun, lead them to think about the world outside the classroom. When it is day, what does it look like? This question will seem odd to the students without a contrasting frame of reference. Ask them what the night looks like, then return to thinking

about the day. The Sun will enter the discussion now, if it had not already. You should now ask again what happens during the day to make it become night. Can we see that happen? What would we need to do first? Go outside!

Inquiry Investigation

Outside, you should bring an easel with paper and a marker. Without mentioning the direction South, you need to make everyone face South (or North if you are in the Southern Hemisphere). This is important for the observations. While you are doing this, you might want to talk about why it is important that everyone face the same direction (without talking about South) when you are all observing the same object. Facing south is important because in the continental United States, the Sun is in the south at all times. You should not mention this fact at this time. What is important is that everyone should be able to talk about the same viewpoint. Otherwise, imagine trying to talk about a pillow on your bed if everyone else is looking at your door. It will be hard to do unless you have everyone looking at your bed first.

You should then draw the view ahead of you on the paper on the easel. Ask everyone if the details are correct. If not, what should be changed or added? It is the morning during this first observation, and the Sun will be over everyone's left shoulder. Our shadows will be to the right of our bodies. Just noticing that they have a shadow is fun for this age group. Later Threads will provide more time for your students to explore this further.

Ask the students some questions. Where is the Sun? How high is it in the sky? Can everyone think about tree heights or house heights? How about where the Sun should be in the picture? Could we tell from other clues? Some will feel the Sun on their left cheek, and say that is a clue. Few may make the connection between the shadow on their right and the Sun on their left. (This is a great connection which will be explored deeply in later Threads.) Draw the Sun on the easel.

We could, out here in the warmth, talk about our Sun and the heat and light it gives us. How far away do we think it is? What is it made of? How big is it? We don't need to know the real answers for this. We should just be thinking about this great Sun of ours and how much it can affect our world down here.

Return with the easel to the classroom and try to ask where they think the Sun might be in an hour. There will be wild guesses, and that is part of the fun of asking questions in a wondering scientific spirit! They could mark their guesses with mini sticky notes or dots, if you wish.

Return with them every hour to make another drawing. Maybe they can take turns helping you draw the Sun into the easel drawing. How did the guesses turn out? Does anyone have a theory about the movement? Where is the Sun going? What happened to the shadows?

After a few more observations, a definite shape is appearing in the movement of the Sun. This shape is known as an arc, but for the purposes of this younger age group, you can call it whatever you wish. In fact, it would be a good time to compare this shape to other shapes around their world. Some classes in the past called this shape a rainbow, a frown, a big belly, and a bridge. What do they see in this shape? Could they take this shape and draw it in their journals? What do they see? What else can they make from that shape?

The aims of General Science are mainly three:

• 1. To give the student such information as to enable him to understand and interpret his environment.

• 2. To develop in the student the power of observation and teach him to reason from cause and effect.

• 3. To stimulate scientific curiosity.

— Pulvermacher and Vosburgh, *The World About Us*

Second Grade through Fourth Grade

Developmental Issues

Second to fourth-grade age children are better able to reason more time-related concepts, consider two or more variables in thinking about a problem, and begin to plan things for the future. Their skills in dynamic imagery are developing as well as their ability to hold more information in their heads. This makes it possible for them to hold and manipulate the position of images in their minds. This is key to concepts such as predicting from observation or thinking about the movement of two objects, the Earth and the Sun. This Thread will focus on these ideas as directed by our observations. Since students at this age are able and enthusiastic when it comes to reading and writing, an emphasis will be placed on recording data and sharing it with others. On a social level, this age group is typically interested in teams and other social groupings. You may want to consider allowing for this in the investigation, creating teams of illustrators, time keepers, or instructors. It may help students become comfortable with the atmosphere of inquiry-based learning.

Experience with models and analogies helps children learn to understand them. Teachers of students at this level should introduce them and should not shy entirely away from presenting concepts that are slightly beyond the developmental level of their students. Look for ways to support the students' developing understanding with a number of alternative paths to grasping the concept as well.

Inquiry Introduction

Where does the Sun go in the evening? Why does it seem to rise in the morning? What is happening? What is a day for us? We should think more about the outside world and how it knows about a day. Without a clock, what could we look at to know about a day? How could you plan such an experiment? What are the important things to plan when you are about to observe something? How long would it take to get a good idea about what was happening? How would we keep a record of what we saw outside?

Inquiry Investigation

Outside, you should bring an easel with paper and a fresh marker. You may also want students to bring out journals. Without mentioning the direction South, you need to make everyone face South (if you are in the continental United States). This is important for the observations. While you are doing this, you might want to talk about why it is important that everyone face the same direction (without talking about South) when you are all observing the same object. Facing South is important because in the continental United States, the Sun is in the south at all times. You should not mention this fact at this time. Children at this age should be comfortable with left and right,

and can use these words to think about the direction of the Sun. What is important is that everyone should be able to talk about observations taken from the same viewpoint. Otherwise, imagine trying to talk about a pillow on your bed if everyone else is looking at your door. It will be hard to do unless you have everyone looking at your bed first.

What needs to be drawn on the paper? Why should we be so careful about getting our view on the paper? We should think about the fact that we are all about to have an experience outside, and if we want to share it with other people, we should really make sure we've got a good recording of our experience.

Should we look at the Sun directly? No, this will harm our eyes. Even glances are not even healthy. How else could we describe where the Sun is? Some will feel the Sun on their left cheek, and say that is a clue. Others might make the connection between the shadow on their right and the Sun on their left. (This is a great connection which will be explored deeply in later Threads.) Where is the Sun with respect to our bodies? To the school? To that tree over there? How does it feel on our faces or arms?

Now, let us leap into another arena of thinking and ask where on the two-dimensional drawing of our view would we put the Sun? We need to make the connections between the representation of objects on the drawing and the actual objects themselves which are outside in the world. Does everyone have a thought about this, and can they explain it to others? Draw the Sun where everyone agrees it should appear in the picture. Drawing in journals also might be a good idea. Return to the classroom.

In the classroom, talking about what a model is would be a good way to link these two experiences. In the real world, we saw a Sun with respect to our position out in the world, and with respect to the positions of other things out in the same world. The drawing, however, contains our viewpoint, without *us* in the picture. It is a model of the world around us, and we are not in it because it is what we saw *around* us. What is the shape of this model compared to the shape of our world? Is it still an OK picture of what we saw? When we were outside, it sure looked like our view. How is our drawing different from the real view? Think about the three dimensions of the world around us and how paper limits us.

What will happen in one hour? Anything? What will our view look like? Will we need to draw a different picture of the school yard? If not, what will be different in the picture, if anything? Perhaps here the class could break into brainstorming teams to think about where the Sun might be in one hour and why. They should prepare an explanation for the other teams.

Return with them every hour to make another drawing. Maybe here is where teams might help keep records and draw the Sun on the easel view. How did their predictions turn out? Does anyone have a theory about the movement? Where is the Sun going? What happened to their shadows? Can those same teams back in the classroom think some more about the movement they have now seen and how it might be reinterpreted?

After a few more observations, a definite shape is appearing in the movement of the Sun. This shape is known as an arc, but you can call it whatever you wish. Children at this age are really broadening their creative skills, and having them think up their own name for this shape would be fun for them. Some classes in the past called this shape a rainbow, a frown, a big belly, and a bridge. What do your students see in this shape? Could they take this shape and draw it in their journals? What shapes can be made from it, half-circles, circles?

What reasons can we think of to explain why the Sun is making this shape? Do we think that the Sun is really moving around the Earth? Many will come to your class already having been told about the spinning of the Earth, but they will not be able to explain it well. Ask them if they could explain the movement of the Sun with a spinning Earth. Is it important right now that everyone believe the Earth is spinning? No, not really. It is important only that they have had this day-long observation and been able to model it in the classroom on paper. You could ask them to try to get up with a group and recreate their observations in a play, where one person (the Sun) walks around another person (the Earth) during the day, and also where the Sun person is still and the Earth person slowly spins.

So, where does the Sun go in the evening? Could we draw it or write about it somewhere? Could we interview other classrooms who have not had the same experiences as us and see what they think? What about classes who have had the same experiences as we did outside? What do they think? Many will say the Sun goes to the other side of the world. Ask them then what is it like for people on the other side of the world when it is day for us? Can anyone point to a place on the globe which is having night right now? The Internet has a database of live cameras set around the world. Finding the country your students chose and looking at a real “live” picture will help solidify their theory and strengthen their resolve. See page 84 for a list of good Internet sites with live cameras.

Another way of enforcing this experience is to make a Noon Line in your school: either in your own classroom, if we face South, or in a friend's classroom across the hall. For instructions, please see the Additional Resource, **Telling Time Without a Clock**.

Fourth Grade through Sixth Grade

Developmental Issues

Fourth through sixth graders are increasingly able to abstract, reflect, and put one's self into another situation. They are able to reason about time more flexibly. They can manipulate images in their minds and can coordinate the dynamics of more than one image. They also can entertain the possibility of future events and think about hypothetical outcomes. These students are also making connections between what they are experiencing and how it affects their lives; how situations in general can affect lives in general. They also can consider different scenarios and envision whether these fit with their observations. This combination allows us now to explore the passing of the day with respect to objects in motion in a three-dimensional world outside of planet Earth and also to think about experiences happening for people in different places. Also, the level of math acquired by this age lets us talk about our experiences in another language, the language of geometry and numbers. This Thread will present the two theories of the Sun's motion debated by the geocentricists (believers in an Earth-centered Solar System) and heliocentricists (believers in a Sun-centered Solar System). Using the different positions of the Sun during the day as they relate to different positions in time and space, we will probe the data for theories and make models of what we have postulated.

Inquiry Introduction

The passing of a day has long been known and measured to be what? 24 hours. But what does 24 hours represent? How could we watch that happen without a clock? What is happening outside which plots the length of day and night?

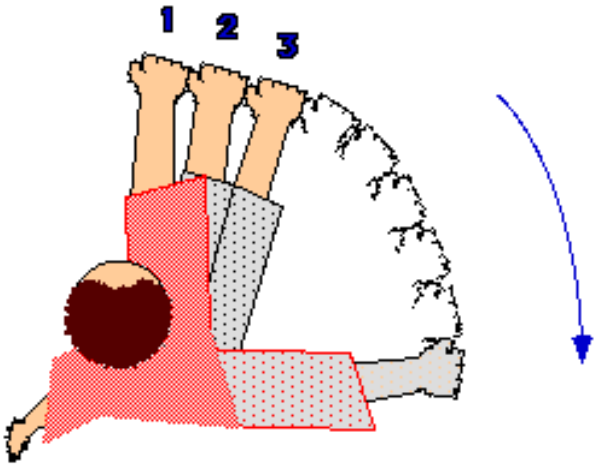
Inquiry Investigation

Outside, you should bring an easel with paper and a fresh marker. Students should bring their journals. Also bring a navigational compass (or enough compasses for the whole class). What time of day is it? Without having already known it was morning, are there any clues around you that might tell you the same thing? How far around the world can we see with our eyes without turning our head?

Ask the students some questions. Which way is North? How could we find out for sure? If a certain direction is North, which way is East? We always learn East is to the right of North. If everyone faces North, East will be on our right hand. This will help ease the perspective problem. The question is, how easily can we see the Sun when facing the North? Have everyone face the South. Which way is South? Is it easier to see the Sun in our view now? OK. We will face South, then. Could we draw

that view? Having everyone bring out their journals is a good exercise here. They can all draw what they are seeing. Ask them what they have done by drawing the world. Is our drawing truly the real world? It is a flat model. How does it compare to the world around us? Is it a good representation of the world? Would someone from another school be able to recognize trees and houses as such in our drawing? Also, draw this view on the easel paper.

Should we look at the Sun directly? No, this will harm our eyes. Glances are not even healthy. How else could we describe where the Sun is? Some will feel the Sun on their left cheek, and say that is a clue. Others might make the connection between the shadow on their right and the Sun on their left. (This is a great connection which will be deeply explored in later Threads.) Where is the Sun with respect to our bodies? To the school? To that tree over there? How does it feel on our faces or arms?



How high is the Sun? How could we measure that? With a ruler? There is a very easy technique called "fist measuring" which can help us without having to use anything but our own bodies. All you need to know is that 90° is the angle difference between holding your arm straight out to the side and straight out in front of you. All you need to do is stand still and put your arm out in front of you at eye level, with your hand in a fist. Close one eye. Carefully begin moving your arm stiffly, watching and counting how many fists you can line up side by side until your arm is 90° away from where you started, or straight out to your side. Use things around the yard as guides to help you count those imaginary fists. The figure helps you see what we are describing. Dividing 90° by the number of fists you counted will give you how many degrees your fist covers! (Hint: In case you are not sure of your answer, an average fist covers 10° on the sky. Your value should be close to this.) Similarly, you can try to calibrate your finger! Try this outside (your finger held at arm's length will cover 1° on the sky.)

Now, let us imagine where on the two-dimensional drawing of our view would we put the Sun? We need to make the connections between the representation of objects on the drawing and the actual objects themselves which are outside in the world. Does everyone have an idea, and can they explain it to others? Draw the Sun where everyone agrees it should appear in the picture. Use the fist measurement tool to relate the Sun's position to the horizon, to nearby buildings and trees, and perhaps to due south. Return to the classroom.

How would we go about making some good observations of the Sun to understand what is happening in a day? Most students will tell you to go out every so often and check. Why? What might change? Does our world change? How has it changed since spring? How will it change in four months? How will it change in five hours? How have we changed in a year? The changing world means we need to keep an eye on it. What is the scale for watching the Sun move in a day? If no one else does, suggest that observations be made every hour. Have the students devise a plan for carrying the easel and markers and making sure journals get collected for observing outside. Does anyone have a clue about where the Sun might be next? Let's all make some predictions with accompanying reasons in our journals.

Return with them every hour to make another observation and drawing. Where is the Sun now? Is it noticeably different? How many fists up in the sky is it? Maybe they can help you draw the Sun in. How did their predictions turn out? Does anyone have a theory about the movement? Where is the Sun going? What happened to their shadows? Many will come to your class already able to tell you that the Earth spins, but they will not be able to explain it well. Ask them if they could explain the apparent movement of the Sun with a spinning Earth. Is it important right now that everyone believe the Earth is spinning? No, not really. It is important only that they have had this day-long observation and been able to model it in the classroom on paper and then later on the board as a geometrical model. We can then talk about our experiences back in the classroom and think of some good explanations for what we saw.

So, where does the Sun go in the evening? We could interview other classrooms who have not had the same experiences as us and see what they think. What about classes who have had the same experiences as we did outside? What do they think? Many will say the Sun goes to the other side of the world. What is it like for people on the other side of the world when it is day for us? Can anyone point to a place on the globe which is having night right now? The Internet has a database of live cameras set around the world. If you are able, access a site and find the country your students chose. Looking at a real "live" picture from that place will help solidify their theory and strengthen their resolve. See page 84 for a list of Internet sites with live cameras.

After a few more observations, a definite shape is appearing in the movement of the Sun, if you use each Sun plot as a dot in an outlined shape. What shape is emerging to describe the movement of the Sun? This shape is known as an arc. How might we extend this shape into a bigger shape? Draw this arc high on the board, leaving room on the sides and the bottom for thoughts about the larger shape of this arc. Ask them if this is the shape they saw the Sun moving in. Students will see a semi-circle and a full circle, some may even be silly and make some squiggle. Perhaps they should put their bigger shape in their journals and give it a name.

Can anyone think of a reason why the Sun is making this shape? Is the Sun moving? Do we think the Sun is moving around the Earth in this shape? Where in our drawing on the board is the Earth? If this is too hard to think about, where then were we in the picture? If the shape were a semi-circle, what would happen to us? Would the Sun go right through us? What about the other side of the Earth. Do people live there? What would happen to their day if the Sun just went zipping past in a straight line like that? Do they think this is probable? What might be a more likely shape for this situation? A circle!

What do we know that is special about a circle? How many degrees are in a circle? How many hours are there in a day? Could we figure out some things about where the Sun might be shining in one hour? What about in five hours? Where will the Sun be? On a globe, we could try to guess this place and look on the Internet. (The Thread, *Time Warp*, begins some thoughts on Time Zones.) England is five hours from Eastern Standard Time, and there is a great Internet site for Cambridge, England, where a live camera takes a wide angle shot of the University there every few minutes. This visual proof can be turned around in such a way: Thinking about a circle seems very mathematical and not related to our world very much. However, if we recall that we made a circle from the motion of the Sun in our experience, then it must be said that what can be predicted from a circle can be applied to the apparent motion of the Sun.

Does that circle mean that the Sun is moving around the Earth? Could there be another way of seeing the Sun do what we've just seen it do? Here is the challenge of perspective, and this will be the most difficult of all. Imagine you were born and lived on a spinning carousel. You've never known the ground. What would your view be like? All around you the world would be spinning past, but the things on the carousel would stay in place. How easy it would be to believe that you are standing still and everything else is moving, if you've never been off of the carousel.

Place a bright light source or even a student at the front of the room. Have the students stand such that their left shoulders are pointing to the light source in the same way their shoulders pointed to the Sun. Ask the students to then say where in their vision does the light source lie. Give them a blank piece of paper. They should say or even draw the light at the very left of their view or paper. Just drawing where the light source is in their view might be superior to drawing the room and the light source. The reason for this is, as they are spinning about past the light source, the room is also appearing to spin. Thus, the idea of the light source appearing to move becomes moot, because the entire room will appear to move. This is not what we saw when we watched the Sun all day long. We saw the Sun appear to move past the scenery. So, perhaps saying that they should draw where the light

source is instead of what they are seeing will help them develop a better mental model of what is happening.

Ask them to turn counter-clockwise until they are facing the light source. Have them again say or draw where the light is in their field of vision. The view will be that there is a room with a light source in the middle. Then ask them to turn again so that the light source is on their right shoulder. Have them tell you about or draw this final view. This time, the room should appear to be filling their view except for the very right side, where there is a light source. They may want to glue or staple the drawings into their journals later.

Putting the pictures in the order of their movement, does anyone see a pattern? Put the easel and its drawing in the front of the room. Does anyone see a connection? What two types of motion do we now know can cause the pattern we have observed? If the light source were the Sun, what time of day would the first drawing represent? Where is mid-day? What would happen if we spin around past the point where the light source was at our right shoulder? Our backs would be to the light source. Is this what happens at night? Ask the students if everyone on the Earth gets sunlight sometime. This will lead into the question of what kind of spinning shape allows that to happen.

Now the big challenge is to find out what the students think this motion means. The light source "Sun" was always at the front of the room, but on the drawing of our turning, we saw it move across our field of view. Is it possible then that the Earth might be the thing that is moving while the Sun actually stands still?

At some point, it would be good to discuss with your students why you had them face South when they were outside. What would happen if we all had faced the other way? Could we go out and see that? We could explore the school's Daymarks by using the Additional Resource, **Telling Time Without a Clock**. What objects around the school could help us to keep track of time without a watch?

"We don't make mistakes.
We just have learnings."
— Ann Wilson Schaef

"Open your eyes and look at the day.
You'll see things in a different way."
— Christine McVie, *Don't Stop*

"It is an important truth that the ultimate reliance of a human being must be on his own mind."

— William Channing

"By honest I don't mean that you only tell what's true. But you make clear the entire situation. You make clear all the information that is required for somebody else who is intelligent to make up their mind."

—Richard P. Feynman

"Science is not the affirmation of a set of beliefs but a process of inquiry aimed at building a testable body of knowledge constantly open to rejection or confirmation. In science, knowledge is fluid and certainty fleeting. That is at the heart of its limitations. It is also its greatest strength."

—Michael Shermer