Tilt-A-World

Purpose

According to the National Science Education Standards, children should know how much the Earth tilts on its axis of rotation. We'd like to make this more of a logical discovery from their experiences than one of those facts they are forced to learn for the sake of "science" tests. It has been shown that most adults do not retain this information from their primary school memorization, so this Thread will try a different route to really learning and understanding this fact about our world. Vocabulary words which can be integrated into this Thread are tilt, seasons, clockwise, counter clockwise, equinox, solstice, and year.

Teacher Background

You will need: set-ups from Latitudes and Attitudes, Internet WWW browser with graphics if possible, paper and pencils.

There is not much time required here to gather materials, since this Thread reuses those from before. You will probably also only need a few class periods to explore this topic and any other related subjects you include. Teachers of higher grades may want to spend more time on this for the geometry opportunities it provides.

This repeats some of the Teacher Background from *Latitudes and Attitudes*. Most of the planets in our Solar System are tilted over on their spin axes. We are not sure why this is so, perhaps it is due to the violent collisions common in the early Solar System when there were thousands of small rogue planets circling the Sun. The Earth tilts over on its axis 23.5° with respect to the axis of the Solar System. This means that the Earth is always "pointing" to one side as it goes around the Sun. So, sometimes the Sun is in the direction that the Earth is pointing, but not at other times.

The effect the tilt has on the Earth is that at some times during the year, Earth's orbit makes the northern hemisphere tilt towards the heat and light of the Sun. The increased height of the Sun above the horizon lengthens the length of time this part of Earth receives daylight as well as the intensity of the light (remember the *Me and My Shadow* flashlight investigation). This increases the amount of light this

area of the world gets, thus the overall temperature there increases, since more time in the light means less time for the land and air to cool down before being lit and hence warmed again. In contrast, at the same time, the southern part of the Earth is receiving less daylight time and less intense light and thus is colder. In the southern hemisphere, they will always have Winter when the north is having Summer, and vice versa.

Spring and Fall however are perhaps the most interesting times of the year from an astronomical point of view. The tilt of the Earth is not directed towards or away from the Sun, so it could be said that these seasons are more like what the planet's weather would be like if the Earth did not tilt at all. This also means that if we have some data from the very middle of either the Spring or Fall seasons and also from the very middle of Summer, we could make a comparison between the amount of sunlight and the tilt of the Earth.

"Science moves with the spirit of an adventure characterized both by youthful arrogance and by the belief that the truth, once found, would be simple as well as pretty."

—James Watson

"The true scientist never loses the faculty of amusement. It is the essence of his being."

—J. Robert Oppenheimer

"The first precept was never to accept a thing as true until I knew it as such without a single doubt."

—Rene Descartes

Kindergarten through Second Grade

Developmental Issues

For this age group, this is a good time to go back and think about seasons, and shadows. Playing with the little trees again (after you've finished another installment of a Winter version of the sun stick investigation when the shadows are longer) will provide experiences to support understandings children develop in later grades.

It does not make sense to focus directly on the Earth's tilt with this age group. It is too difficult because it requires thinking about models and thinking hypothetically at the same time. It entails a big cognitive load to reason that the Earth must be tipped because it explains all of that data. This introduces a dilemma. You could just tell your students and then have them see how the explanation fits the data. That would be a good way to handle it but then, the answer you give makes it less likely that older students will actually go back and consider the question in earnest in future years. What to do? Think more about the seasons and our shadows.

Inquiry Introduction

Why when we were outside did things change so drastically? What is happening out there? Why do we have seasons? Why can't it be nice and warm all of the year? What is happening on our world? Why does it get cold? What happened to our shadows of the tree? Why could they get longer? Did the tree grow that much bigger in just a few months? What could have happened if the tree didn't move?

Inquiry Investigation

Get that globe with the blue-tak and little tree. Aim the lit overhead projector towards the globe. How could we make those shadows of the tree get longer? How did we play with flashlights to make longer shadows? We tilted the flashlights. Does the big Sun tilt itself every year? How can you tilt something that is light all over the place? What else could you tilt? Did the tree tilt? Maybe the world tilted?

Tilt the globe a little away from the overhead projector. What happened to the shadows? They got longer. Is that like what happened to the shadows of our tree? Could they get shorter again? How could we check that this had happened? Go back outside to see at some other time. How long might it take before those shadows get longer again? Let's go out then in about four months.

Is the world really tilting like that? Wouldn't we feel it if it did that all of a sudden? "Maybe it tilts slowly," someone might say. What might cause this? Let's try to think of why the world might do this, or if it really could.

Second Grade through Fourth Grade

Developmental Issues

Thinking about this tilted world system is possible in these grades, but must be approached concretely and in lots of different ways. Making some teams to play with globes and lights will help them to grow into this idea from experiences. The upper grades will come to studying the tilt with the benefit of some math to use as a means of additional experiences. But for this age level, we will mostly rely on what we've learned about how light and angles work together. Students in this age group can grasp these variables when approached from a hands-on experience.

Inquiry Introduction

The seasons are rapidly changing outside in our world – is there anything we can do about it? Nope. We are living on a world that is changing. But what is causing these changes? Is it a sudden thing? How often does it happen? This kind of thing has been happening forever, every year. What happens in one year to the world? The world moves once around the Sun in one year. Is there something that happens to it at different points on its trip that causes the seasons?

What might make it warmer? Many will say getting closer to the Sun would warm things up. Does that mean Summer happens when we are closer to the Sun? So, does the whole world have Summer when the Earth gets closer to the Sun? Some will then shake their heads because somewhere they know that other places are having Winter when we are having Summer. Oops.

Inquiry Investigation

Find those places on the world that we looked at in Latitudes and Attitudes. Check to see how many of those have live camera Web sites from the list on page 84. Ask the class: What season are we in now and what does that look like? If we could see these other places right now, we should look for those signs of the season there. If they are not there, what might that mean about the season? If you don't have access to the Internet, move on to the next page.

If you are in the Northern Hemisphere, places like South Africa provide awesome displays of this difference. If it is presently Winter for you, why are there flowers and green trees in South Africa? Look at more sites which are in the opposite hemisphere from yours as well as sites in your same hemisphere, without mentioning the term "hemispheres" just yet. What is the pattern here? Are there specific portions of the world where everyone seems to be having the same seasons we are, while others are experiencing the opposite season? What is the biggest pattern: our top half of the world has one season, but the other half does not. How can that happen?

Aim the overhead projector at the globe. How does the light hit the world? Use the example from above and consider: Is there much difference between how it hits us and how it hits Australia? Is it possible for these people to have a different season than we are having with the world like that? Could we move the globe around to try it out? Is it possible to make only one half of the world get warmer than the other? They may see where this is going, and say tilt the one half away or towards the light to make it warmer. If they don't, tilt it yourself and ask them what would happen if the Earth were tilted like this. How warm could this bit get as compared to the other bit?

But how does this change during the whole year? What does the world do in a year? It goes around the Sun. Does it wiggle back and forth as it goes? What would that be like? What if it just went so that sometimes it was flopped over towards the Sun and sometimes not?

Have a student be the Sun in the middle of a space in the room. Walk around her with the tilted Earth and stop at a point where your hemisphere is pointing toward the Sun. What season is this for us here? Summer. Move counter-clockwise 90° around the Sun person. What about here? It is Autumn or Fall. Keep going around another 90°: what about here? Winter – see our half is pointing away from the Sun. Move to the Spring space and ask again. Spring is here, and then on to...Summer.

"We especially need imagination in science. It is not all mathematics, nor all logic, but it is somewhat beauty and poetry."
—Maria Mitchell

"To learn something new, take the path that you took yesterday."
—John Burroughs

Fourth Grade through Sixth Grade

Developmental Issues

We don't need to sneak up on the subject for this age group. Doubtless they've already been told somewhere that the world is tilted, but it is unlikely that they could demonstrate, using their own experience, how the tilt works through the year. They will want to make the world wiggle over on one side and then the other. So, we should combine the measurement data collected from the Equinox and Solstice versions of the sun stick data.

Inquiry Introduction

What causes the seasons? Most will say that the tilting of the Earth is the cause. Does this tilt change during the year, then, in order to change the seasons? Is there any other way to make the seasons happen without the changing tilt?

Inquiry Investigation

Stick those golf tees on some towns used from Latitudes and Attitudes. Shine the overhead projector on the globe. What do the shadows of the tees look like? How do we make them longer or shorter? Tilt the globe one way or the other. What does that mean about the light that hits the globe? Look at the intensity of the light on the tilted part versus the non-tilted part. What does it look like? Would it be warmer or colder there? How does this pattern change during the year? How does the Earth orbit the Sun?

Have a student be the Sun and stand in the middle of a space in the room. Walk around her with a tilted Earth globe. Remember to aim your tilt at a point on the wall so that you keep the tilt direction always still, even if the Earth is moving around the Sun. A look back to the diagram in Latitudes and Attitudes might be good for preparing your role in this activity. Stop at a point where your hemisphere is pointing at the Sun. What season is this for us here? Summer. How long is the Sun out? Do you think the daylight time might be shorter or longer with that much Sun? When does the longest daylight time of the year occur? Why? And what is the temperature at this time of year?

Move counter-clockwise 90° around the Sun person. There is a drawing to help you within this Thread. What about here? It is Autumn or Fall. Are we tilted towards or away from the Sun? Would that cause any significant change in the temperature here? The tilt must be towards or away from the Sun in order to make a season with extreme temperatures like Winter or Summer. If the Earth had no tilt at all, life on the Earth would be very much like having Autumn all of the time. Is there any other season that might also not have a tilt towards or away from the Sun? It is Spring! How long might daylight time last during these seasons? Since there is no

tilt factored into the Sun height, and the Sun is aimed at the middle of the Earth, it may be that the daylight time is in the middle, or half of 24 hours. It is a thought.

Keep going around another 90°: What about here? Winter – see our half is pointing away from the Sun. How long are the days here? How long are the shadows here? When does the shortest day of the year occur? And what is the temperature at this time of year? How many days are in between the Summer and Winter times? How far around the Sun has the Earth traveled? The Earth has traveled to the opposite point of its orbit around the Sun. This is why the tilt seems to be "aimed" in exactly the opposite direction. The tilt didn't wobble and the Sun didn't really move—the Earth orbited around to a position where the tilt direction was now pointed away from the Sun. Move to the Spring space and ask again. Spring is here, and is there a tilt away or towards the Sun? So what can we say about this time? And then move on to...Summer again.

What do we all mean by Summer, then? Is it global Summer? No, it is hemispherical Summer. We should be careful to make sure we are certain which hemisphere we mean when we talk about Summer! So, when it is Summer for the U.S., for example, our part of the Earth is tilted towards the Sun. How might that change the Sun's apparent height in the sky for us? Would it seem higher or lower if we tilted back from it? Try rocking forward or backward in your chair while looking at a circle on the board. How high does it seem when you lean forward? Backward? It seems to sink when you lean back. So, a lower Sun in Winter. What would happen then to the shadows of trees if the Sun were more low in the sky?

Shine the overhead on the globe again. Repeat the seasons demonstration with the student standing in the middle of the room as the Sun. What are the shadows like for tees or people in different places? Shadows are lengthening for people as their "Winter" begins. Cool. We've been measuring shadow stick lengths throughout the year and can probably see the same thing in our data. And what do the shadow lengths tell us about the height of the Sun? In turn, what does the height of the Sun tell us about the amount of the Earth's tilt in the Sun's direction?

How much does the Earth really tilt? How could we ever find out? The longest day of the year happens when the Earth's northern part is directly aimed at the Sun and the shortest day is when the Earth's northern part is directly aimed away from the Sun. These longest and shortest days are when the tilt of the Earth is at its most extreme orientations with respect to the Sun. Don't forget, at the equinoxes, there is no tilt factoring into the Sun height because the tilt direction is pointed perpendicular or 90° to the line between the Earth and the Sun. Can these facts help us find the degrees of the Earth's tilt?

What was the height of the Sun at mid-day on the Winter solstice? What about on the Autumn or Spring equinox? What is the difference in height of the Sun between the equinox and the next solstice in fists or in true angles? If you have managed to get measurements for both equinoxes, brilliant! What is the difference between the solstice and the other equinox? They will be able to see that the difference is always around 23.5 degrees no matter what. The accuracy of their findings will depend upon how carefully they made their measurements.

Twenty three and a half degrees is the tilt of the Earth with respect to the flat orbit it makes around the Sun. They can check this number in a book or on the Internet if they choose, but now they know exactly how to find it again, just by using their own observations and data.

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"Discovery consists of looking at the same thing as everyone else and thinking something different."

— Albert Szent-Gyorgyi

"We have to abandon the idea that schooling is something restricted to youth. How can it be, in a world where half the things a man knows at 20 are no longer true at 40 -- and half the things he knows at 40 hadn't been discovered when he was 20?"

—Arthur C. Clarke