Creating Science – Sundials

How can we tell the time without clocks, smartphones or watches? Maths, geometry, science, and time. It's all required for this project, whose noble progenitors are thousands of years old. #CreatingScienceSundials

Suggested outcomes

(NOTE: This is by no means an exhaustive list of possible outcomes, neither is it intended that ONLY these outcomes should be met. Science is a deeply interrelated activity; all outcomes at all levels, when appropriate, should be integrated.)

Science understanding

- Earth and space sciences 3 - Earth's rotation on its axis causes regular changes, including night and day (ACSSU048).
- Earth and space sciences 1 - Observable changes occur in the sky and landscape (ACSSU019).

Science Inquiry Skills

- Questioning and predicting 3 - With guidance, identify questions in familiar contexts that can be investigated scientifically and make predictions based on prior knowledge (ACSIS053).
- Planning and conducting 3 - With guidance, plan and conduct scientific investigations to find answers to questions, considering the safe use of appropriate materials and equipment (ACSIS054).

Science as a human endeavour

- Use and influence of science 5: Scientific knowledge is used to solve problems and inform personal and community decisions

Science vocabulary words

Tier 1 (Everyday words) – sun, dial, sundial, shadow, rotation, time.

Tier 3 (Specialised vocabulary)

- Sundial – a device for telling the time using the position of the sun.
- Hemisphere – half the side of a sphere. The shadows tend to point north in the northern hemisphere of the Earth, and will tend to point south in the southern hemisphere.

Warning

- Cutting implements; please exercise all caution and manage age appropriate behaviours.
- This activity requires a sunny day. Please use hats, sunscreen, etc., and remind students to avoid looking directly at the sun.

Preparation

⇨ Copy as many pages of the activity as you feel you will need.

To make the sundials you will also need

- Cutting implements
- Drawing implements to name and personalise your sundials
- Sticky tape to hold it all together
- A means of finding north, most smartphones have a compass that can help

Learning Intent (student friendly)

'We are learning to' (WALT) - build a device that lets us know the approximate time using only the sun and shadows.

Success criteria

'What I'm looking for' (WILF) – a successful sundial and clear explanation.

Student learning goals

Help students make a self-monitored learning goal for this lesson, such as make a proper sundial, or predict when the bell will ring using the sundial.

Evidence of learning

How will you know when the learning goal is achieved? What EVIDENCE do you have that your students have met or exceeded the learning expectations?

Suggestions for other year levels

As always, more material is presented here than can be used by the average class during the average lesson time. However, since the students' questions can and should guide student learning, more material is presented for your convenience. Remember, it is not uncommon for students to only remember those points which answered their personal questions.

Younger:

Children at this age can have difficulty with focus. Avoid tangents if you're attempting to make a key point.

Teen:

It's little effort add challenge to the project of making a sundial! Just add some of the activities suggested in the Elaborate section. Giving extra points for exactness and accuracy potentially increases the difficulty of the sundial project enormously. A sun dial that is accurate to the minute across an entire year is almost impossible as it invariably has to take into account the tilt of the earth and exact latitude of the observer.

Engage

⇨ Make sure all students write down any questions they may have generated during this phase regarding the topic for today.

Question Fest

A Question Fest (short for festival) works best with enthusiastic groups who are confident in asking their own questions. Shyer students might take time to warm up to this form of activity.

Basically, share an interesting point about the topic, such as found on the 'fun facts about the sun' poster from the appendix, and then allow students to ask questions about this topic or fact. Demonstrate lifelong learning by:

- If you can answer the question or fact, do so, with a measure of tentativeness[1], such as; 'I understand that', or 'I have recently read that', etc. All knowledge belongs to someone.
- If you don't know the answer, praise the student, suggest they write the question down. If you can look it up right now: internet search, ask a parent or local expert.

You might even like to focus the students with a game of hangman for the word Plasma, since it's a fun key conceptual outcome for today.

Shadows and the sun

If you want, you can try the following activity. Use a temporary mark (such as chalk) to measure the position of a shadow. Set up a stick, or take a shadow of a tall building.

Allow students to observe the mark, then go away for ten minutes or so (perhaps even an exact hour) and observe how the shadow has moved.

⇨ Ask students to share suggestions as to why the shadow seems to have moved.

They will often default to the reply that it is because the sun has moved. You may wish to remind them that the sun does not move relative to the earth, so how does the shadow move.

* You can even illustrate the concept that the shadows will appear to move along the earth using a small toothpick stuck to a model of planet earth. Using a bright light to simulate the sun, it can be seen that the shadow will turn and lengthen depending on the time of day. (See appendix)

⇨ As students to imagine a world with no mechanics or electricity. How are we going to be able to tell the time? Can you think of a way to roughly guess the time using only shadows?

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[1] This tentativeness is informed by a constructivist pedagogy – basically, it is a cool way to demonstrate to students that we are *Creating Knowledge* together, that knowledge belongs to someone and isn't automatically 'true' because someone calls it 'science'. This is also important, because scientific knowledge changes over time, a valuable case in point is that we now consider plasma a 4th state of matter, when as I child there were only 3 states of matter, and plasma was a special kind of gas. We changed our mind about that fact. So having a measure of caution and tentativeness about scientific knowledge helps students to be open minded about what they are told. Finally, it's a good reason to be tentative, because sometimes we are wrong and don't know it!

Explore

⇨ Encourage and validate student explanations of this phenomenon. Remember, 'I don't know' is a valid explanation in science – it is the beginning of learning new things!

If you'd like, try out the activity 'build your own sundial' in the attached documents.

A few hints:

- When you're done, the pencil should stick out at right angles to the dial. That is, it should be perpendicular to the sundial's face (not to the base). You may need to *tape it down* to a piece of **cardboard** to keep it pointing in the all-important direction.
- It's not very hard nowadays to find your current **latitude** (or position on the face of the earth in the poles – equator direction). Just type it into a search engine, look up http://en.mygeoposition.com/, or take about 27 if you're in Brisbane, Australia.
- Near the equinoxes, around March 20th and September 23rd, the Sun's rays hit the readout face edge-on, and the shadow only forms off the readout face.
- Feel free to use thicker paper, or mount the project on cardboard.

Explain

Help students to understand and explain the science behind the sundial. This includes but is not limited to:

- Light travels in a straight line, and is blocked by opaque objects.
- The earth is a ball shape, floating around the sun in space.
- As the earth turns, the shadows of stationary objects will appear to move.

These are all important ideas, since the concepts behind them cannot be directly observed – only imagined or believed from pictures students themselves did not make.

With care and preparation, we have made a sundial that will fairly reliably help us to determine the time.

This design for learning how to make a sundial is called an *equatorial sundial* because the face with the numbers is parallel to Earth's equator. That's right… if you could see your sundial from space, the face of the sundial would line up perfectly in a parallel line with the planet's equator – at least, in theory!

Imagine that you were holding a tall stick in the middle of summer – at the South Pole. Over a 24 hour period the shadow would move around you, staying almost exact the same length the whole time. It would act just like a 24 hour clock, in fact, you could mark off all the times on the snow.

The stick in this example is parallel to the pencil in your sundial, and the face of the snow-clock is parallel to the face of your sundial. Even if you move your sundial up toward where you live, it will work in very much the same way.

Elaborate

Making sun dials exactly accurate can be a massive task:

- We divide the earth into 24 time zones, for convenience. But the actually position of the sun can differ quite a bit, as much as a whole hour's difference in some places of the world. That is, what we call the 7pm sunset, a nearby city within the same time zone might still consider it the 7pm twilight!

Think of ways to mess up a sundial (apart from breaking it, of course). Some include:

- If the sun went out, would a sundial still work? Is it possible to invent a 'stardial'? (actually, we can and do)
- If the earth's rotation changed, no sundials would be accurate until the change in rotation settled down, and then we made new sundials.
- Trick observers by creating a bright light (on a cloudy day) from the wrong angle to the sun.

Investigate the long and respectable history of sun dials. Which cultures were the first to develop them? Which had a day different to the 12 hours we use?

Explore the difficulties in setting up a sundial; including knowing your latitude, enacting exact measurements, dealing with the imprecision of dials and needles, and dealing with rainy days.

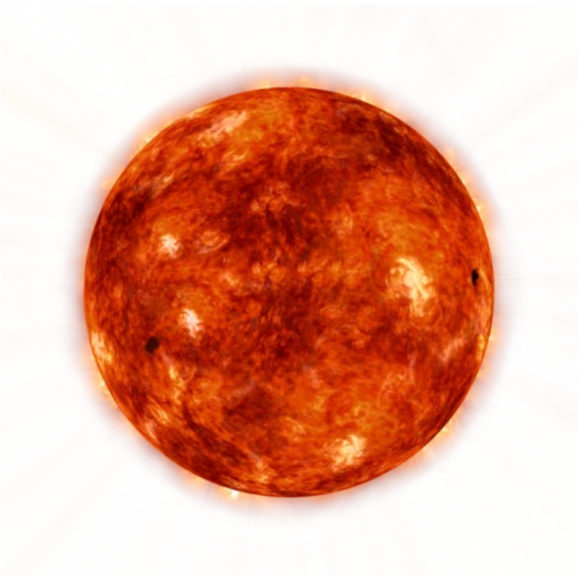
Learn how your sundial's results will differ across the seasons due to the tilt of the earth.

Study the history of the round-Earth theory that is necessary for us to build sun dials that work reliably. Who first came up with the idea?

The sun is a miasma of incandescent plasma

We only tell little kids that the sun is a ball of 'fire', because that's what they can relate to. It's hot, it's bright, and it's dangerous.

However, fire as we've learned in the book Creating Science needs oxygen, and the sun does not need to burn oxygen to glow. Also, fire is a kind of air, and air does not conduct electricity very well. On the other hand, the sun is the most powerful electromagnet in the solar system!



It's more accurate to think of the sun as a giant ball of plasma, fuelled by enormous nuclear power.

With respect to this, the band 'They might be giants' even updated the old science song (https://www.youtube.com/watch?v=3JdWlSF195Y) on the sun to a more scientifically contemporary one (https://www.youtube.com/watch?v=r6q3s1MI6NE). Scientific knowledge changes!!

Evaluate

- ⇨ Review with students what they felt they learnt from this lesson. Did they have any questions at the start that they feel were answered?

Success criteria

- ⇨ Review the Learning Intentions of this lesson with students. Was it met?

At the end of each class, review the learning objective and see how we did. Ask:

- ⇨ Did you achieve your learning goal?
- ⇨ What worked to help you achieve it?
- ⇨ What might you do better next time?
- ⇨ (If needed) where can you go for extra help or information?

Assessment

Prior learning:

Take time to focus on planned content material during the engage phase, for example, ask students how they think we can tell the time without clocks and watches.

Formative:

Focus on planned content material during the engage phase, for example, ask students how they think shadows can be used to tell the time.

Summative:

Help students consider ways they can communicate their new understanding to others, just as scientists need to do.

Creating science

Science understanding

As we learnt to tell the time using the sun and shadows, we needed to understand that;

- Earth and space sciences 3: Earth's rotation on its axis causes regular changes, including night and day (ACSSU048)
- Earth and space sciences 1: Observable changes occur in the sky and landscape (ACSSU019)

Science Inquiry Skills

As we build a sundial to tell the time:

- Planning and conducting 1: Use informal measurements to collect and record observations, using digital technologies as appropriate (ACSIS026)
- Planning and conducting 3 - With guidance, plan and conduct scientific investigations to find answers to questions, considering the safe use of appropriate materials and equipment (ACSIS054)

Science as a human endeavour

As we saw how people solved to problem of learning to tell the time using sundials, we saw that;

- Use and influence of science 5: Scientific knowledge is used to solve problems and inform personal and community decisions

Thanks

I am indebted to http://www.skyandtelescope.com/astronomy-resources/how-to-make-a-sundial/ for their presentation of this design.

Appendix: Shadows on the Earth

Mid-morning – Brisbane

Mid-day, Brisbane time. Note shadow is pointing south.

Goodnight Brisbane!

Appendix: The Sun

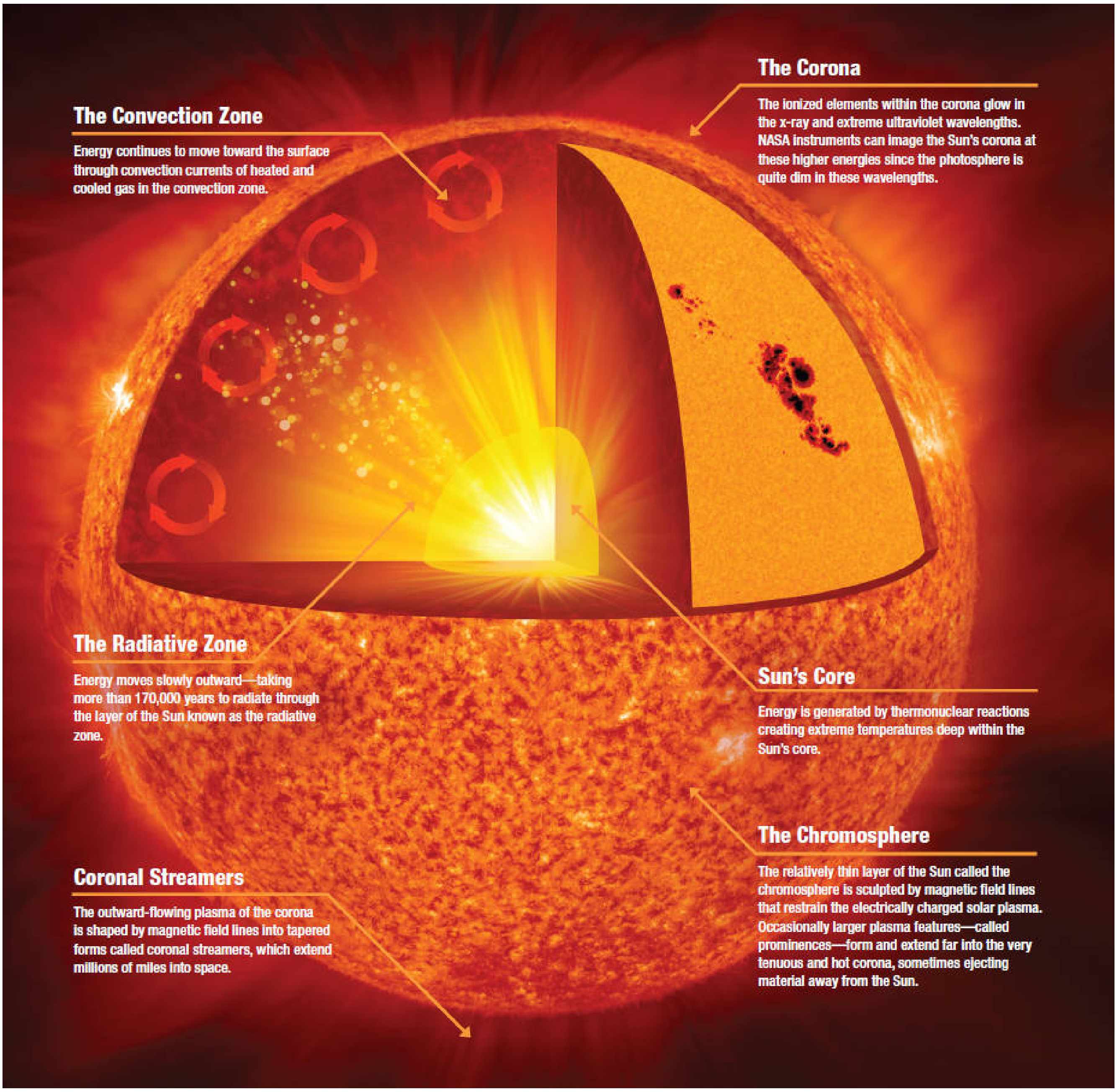
Fun Facts About the Sun

- The sun is a ball of plasma, not 'fire', as fire needs oxygen and there's practically none in space, and fire (as air) does not conduct electricity well, but plasma does.
- Age: 4.6 Billion Years
- Type: Yellow Dwarf (G2V)
- Mass: 1,989,100,000,000,000,000,000 billion kg (333,060 x Earth)
- Diameter: 1,392,684 km
- Circumference at Equator: 4,370,005.6 km
- Surface Temperature: 5500 degrees Celsius
- Thus, the Sun is not the biggest type of star in the universe, but it is definitely larger than most.
- The Sun alone contains 99.8% of the total mass in the Solar System.
- About one million Earths could fit inside the Sun.
- The sun is white. Due to scattering, the red/yellow light travels in almost straight lines, but the blue/ purple are scattered about the sky. The sun LOOKS yellow because so much of the blue light is taken out to make the sky glow blue. If you really want to know what colour our sun makes the most of, it's green.
- While the surface layer of the sun is thin, much thinner than average air, the inner core is compressed much more than concrete. Overall, the sun has a density about that of water, but it wouldn't feel that way if you tried to stand on it!

(The following points are from https://theplanets.org/the-sun/ taken 31 jan 18)

- One day the Sun will consume the Earth. The Sun will continue to burn for about 130 million years after it burns through all of its hydrogen, instead burning helium. During this time it will expand to such a size that it will engulf Mercury, Venus, and Earth. When it reaches this point, it will have become a red giant star.
- The energy created by the Sun's core is nuclear fusion. This huge amount of energy is produced when four hydrogen nuclei are combined into one helium nucleus.
- The Sun is almost a perfect sphere. Considering the sheer size of the Sun, there is only a 10 km difference in its polar and equatorial diameters – this makes it the closest thing to a perfect sphere observed in nature.
- The Sun is travelling at 220 km per second. It is around 24,000-26,000 light-years from the galactic centre and it takes the Sun approximately 225-250 million years to complete one orbit of the centre of the Milky Way.
- It takes eight minutes for light reach Earth from the Sun. The average distance from the Sun to the Earth is about 150 million km. Light travels at 300,000 km per second so dividing one by the other gives you 500 seconds – eight minutes and twenty seconds. This energy can reach Earth in mere minutes, but it takes millions of years to travel from the Sun's core to its surface.
- The Sun will eventually be about the size of Earth. Once the Sun has completed its red giant phase, it will collapse. Its huge mass will be retained, but it will have a volume similar to that of Earth. When that happens, it will be known as a white dwarf.
- The Sun is halfway through its life. At 4.5 billion years old, the Sun has burned off around half of its hydrogen stores and has enough left to continue burning hydrogen for another 5 billion years. Currently the Sun is a yellow dwarf star.
- The distance between Earth and Sun changes. This is because the Earth travels on an elliptical path around the Sun. The distance between the two ranges from 147 to 152 million km. This distance between them is one Astronomical Unit (AU).
- The Sun rotates in the opposite direction to Earth with the Sun rotating from west to east instead of east to west like Earth.
- The Sun rotates more quickly at its equator than it does close to its poles. This is known as differential rotation.
- The Sun has a powerful magnetic field. When magnetic energy is released by the Sun during magnetic storms, solar flares occur which we see on Earth as sunspots. Sunspots are dark areas on the Sun's surface caused by magnetic variations. The reason they appear dark is due to their temperature being much lower than surrounding areas.
- Temperatures inside the Sun can reach 15 million degrees Celsius. Energy is generated through nuclear fusion in the Sun's core – this is when hydrogen converts to helium – and because objects generally expand, the Sun would explode like an enormous bomb if it wasn't for its tremendous gravitational pull.
- The Sun generates solar winds. These are ejections of plasma (extremely hot charged particles) that originate in the layer of the Sun known as the corona and they can travel through the solar system at up to 450 km per second.
- The Aurora Borealis and Aurora Australis are caused by the interaction of solar winds with Earth's atmosphere.

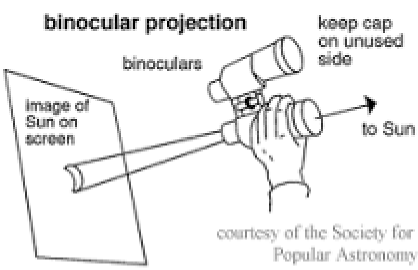
Anatomy of the sun



Taken 31 Jan 2018 https://www.nasa.gov/mission_pages/sunearth/science/solar-anatomy.html

Seeing sunspots

One safe way to observe **sunspots** or eclipses is to project an image of the Sun through a telescope or binoculars onto a white screen -- paper plates, walls and sidewalks all work nicely. If you're using a telescope, be sure that any small finder telescope is capped. DO NOT LOOK AT THE SUN DIRECTLY



Do-it-yourself Sunspot Watching - Space Weather
spaceweather.com/sunspots/doityourself.html

This is very tricky – good luck! Look for a day with known sunspots or an eclipse for best results.