Yogyakarta

STEM Project

DIRECTED INQUIRY THROUGH REPRESENTATION CONSTRUCTION

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SCHOOLS

A scientific concept or mathematical proficiency is not simply an idea embedded in curricular documents and textbooks but consists of a set of interlinked representations and practices

Earth & Space Science

Predictable phenomena on Earth, including seasons and eclipses, are caused by the relative positions of the sun, Earth and the moon

Measurement & Geometry

Establish the formulas for areas of rectangles, triangles and parallelograms and use these in problem solving

Representations

Representations play a fundamental role in the teaching and learning of mathematics and science.

A representation is something that explains some aspect of nature. They can take many different forms or modes.

Representations are the means by which we understand, and communicate our mathematics and science understandings.

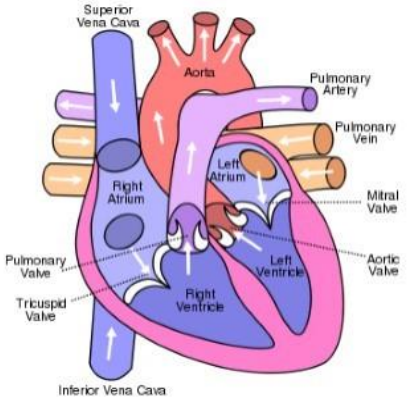
What types of representations are used by teachers in the classroom?

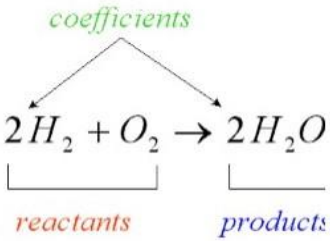
Some representations in science & mathematics

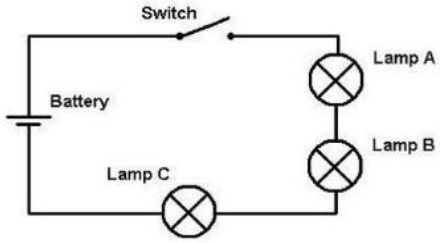
- Diagrams (everyday versus scientific/mathematics diagrams).
- Language (everyday versus scientific/mathematical language)
  - Written form
  - Oral form
- Meaning of the language can change depending on the way in which it is spoken (intonation in the voice) and written (formatting in terms of bold; italics and headings).
- Language in everyday and scientific/mathematics forms makes use of metaphor and analogy.
  - The plum pudding model of the atom.
  - Balancing equations
- Drawings and photographs (can vary from the concrete to the abstract).
  - Photographs of animals in the wild – what is being represented here?
  - The power of electron microscope images.
  - Photographs of geometrical shapes in the real world.

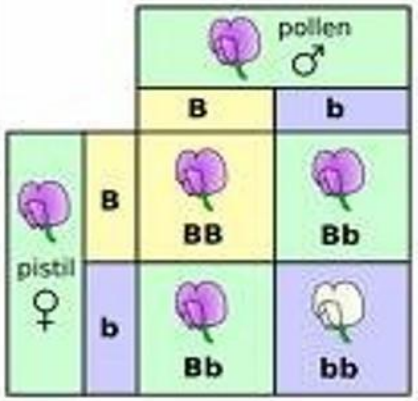
Some representations in science & mathematics

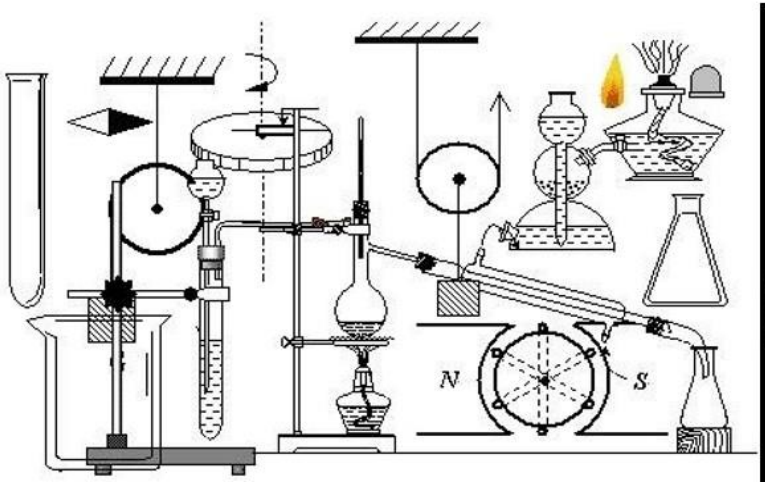
- Embodied representations that include role plays and gestures.
  - Can a student gain more from the teacher if he/she can see as well as hear the teacher?
  - Role-play of sound transmission – particles don't move with the travelling vibrations (a kinaesthetic experience).
  - Directed number role play.
- Mathematical
  - Tables
  - Units/ prefixes
  - Algebraic forms – equations.
  - Graphs – linear for continuous data; bar graphs for discrete.
  - Number (light year; standard form).
- Symbolic
  - Arrows/vectors for forces.
  - cm, °C, (x, y).
- Physical models
  - Platonic solids.
  - Skeleton model of a human.
  - Fish tank full of a sample from a pond.

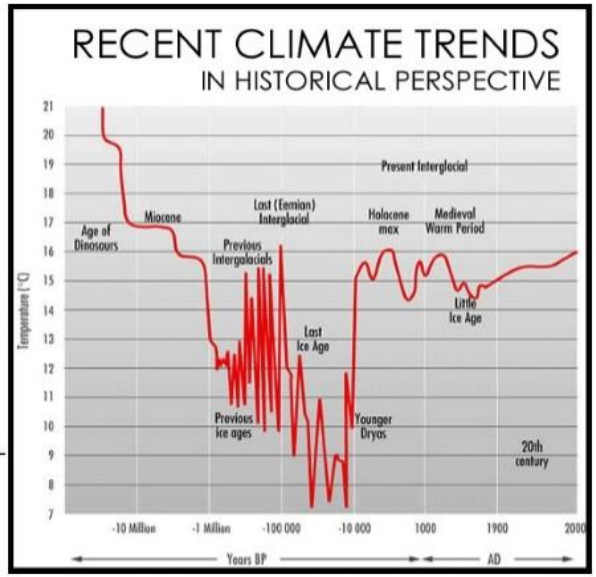

Superior Vena Cava
Aorta
Pulmonary Artery
Pulmonary Vein
Left Atrium
Right Atrium
Mitral Valve
Pulmonary Valve
Left Ventricle
Aortic Valve
Tricuspid Valve
Right Ventricle
Inferior Vena Cava

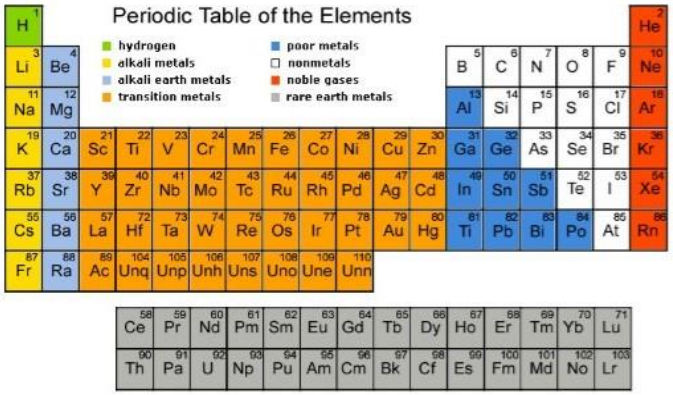

coefficients
$2H_2 + O_2 \rightarrow 2H_2O$
reactants
products

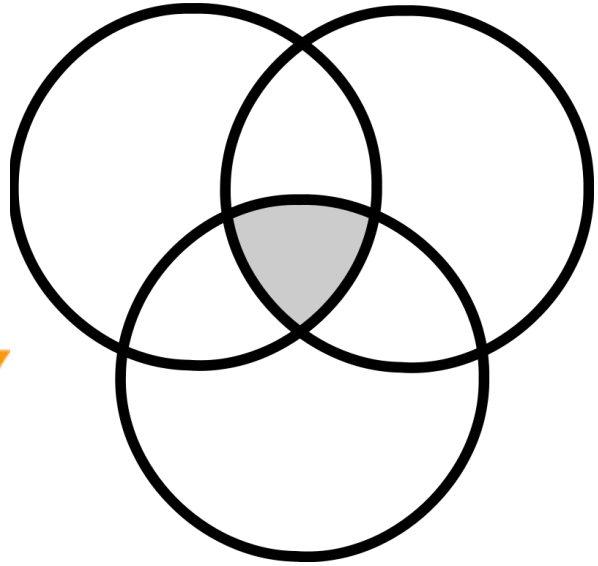

Switch
Battery
Lamp A
Lamp B
Lamp C

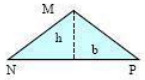
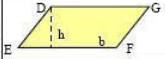
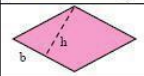
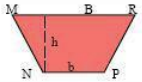

pollen ♂
B
b
pistil ♀
B
b
BB
Bb
Bb
bb


N
S

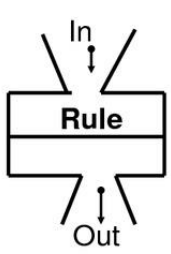

RECENT CLIMATE TRENDS
IN HISTORICAL PERSPECTIVE
Temperature (°C)
Present Interglacial
Age of Dinosours
Miocene
Last (Eemian) Interglacial
Previous Interglacials
Holocene max
Medieval Warm Period
Little Ice Age
Last Ice Age
Previous Ice ages
Younger Dryas
20th century
-10 Million
-1 Million
-100 000
-10 000
1000
1900
2000
Years BP
AD


Periodic Table of the Elements
hydrogen
alkali metals
alkali earth metals
transition metals
poor metals
nonmetals
noble gases
rare earth metals
H He
Li Be B C N O F Ne
Na Mg Al Si P S Cl Ar
K Ca Sc Ti V Cr Mn Fe Co Ni Cu Zn Ga Ge As Se Br Kr
Rb Sr Y Zr Nb Mo Tc Ru Rh Pd Ag Cd In Sn Sb Te I Xe
Cs Ba La Hf Ta W Re Os Ir Pt Au Hg Ti Pb Bi Po At Rn
Fr Ra Ac Unq Unp Unh Uns Uno Une Unn
Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu
Th Pa U Np Pu Am Cm Bk Cf Es Fm Md No Lr

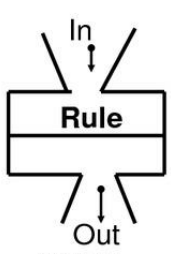


NAME	FIGURE	AREA	PERIMETER CIRCUMFERENCE
TRIANGLE		$A=\frac{b\times h}{2}$	$P=MN+NP+PM$
PARALLELOGRAM		$A=b\times h$	$P=DE+EF+FG+GD$
RHOMBUS		$A=b\times h$	$P=b+b+b+b$ $P=4b$
RECTANGLE		$A=L\times w$	$P=L+w+L+w$ $P=2L+2w$
SQUARE		$A=l^2$	$P=l+l+l+l$ $P=4l$
TRAPEZOID		$A=\frac{(B+b)\times h}{2}$	$P=MN+NP+PR+RM$
CIRCLE		$A=\pi r^2$	$C=2\pi r=\pi d$

BODMAS

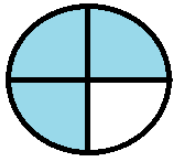


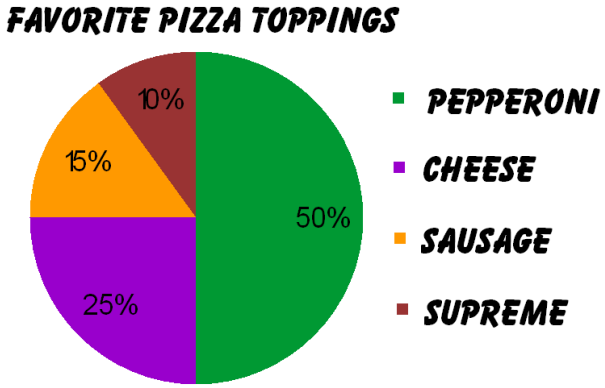
In	Out

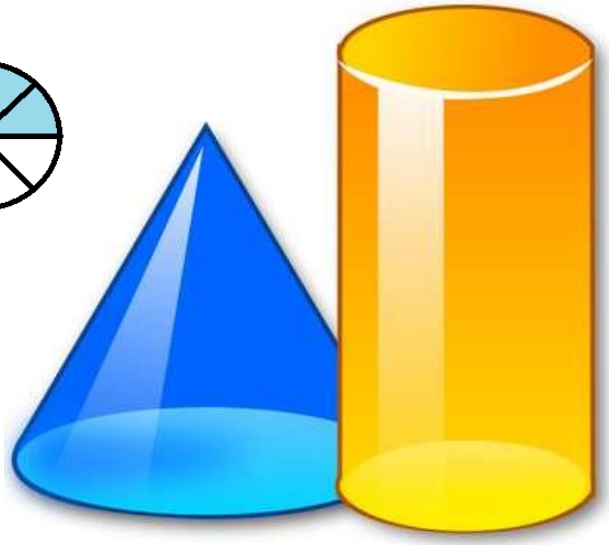


In	Out

$$\frac{3}{4}\times\frac{2}{2}=\frac{6}{8}$$







My group's understanding of a concept

Representational Challenge:

As a group your task is to use the small whiteboard to show the group's understanding of the concept of *the term allocated to your table*.

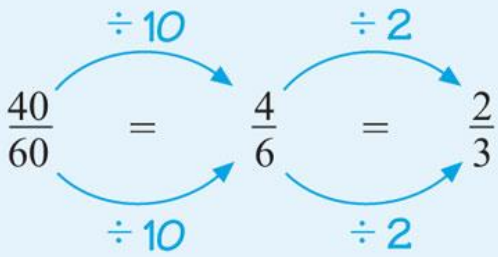
For science the concept is Temperature
For mathematics the concept is Two Thirds

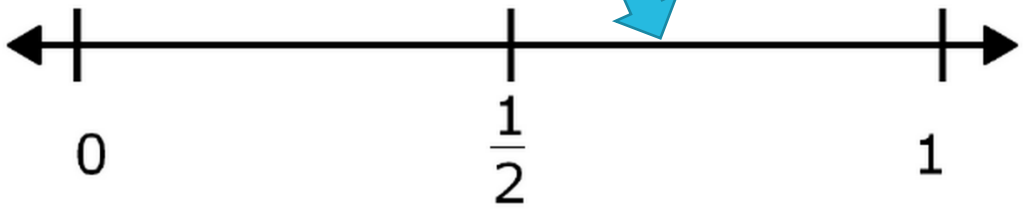
Recurring Decimal

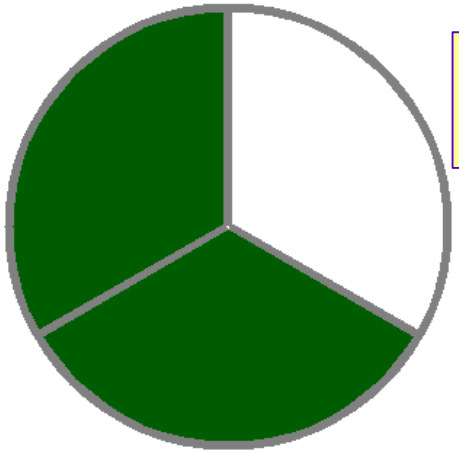
$$\frac{2}{3} = 0.66666\ldots, 0.\overline{66}, \approx 0.667$$

$2/3$

Vulgar Fraction
Rational Number







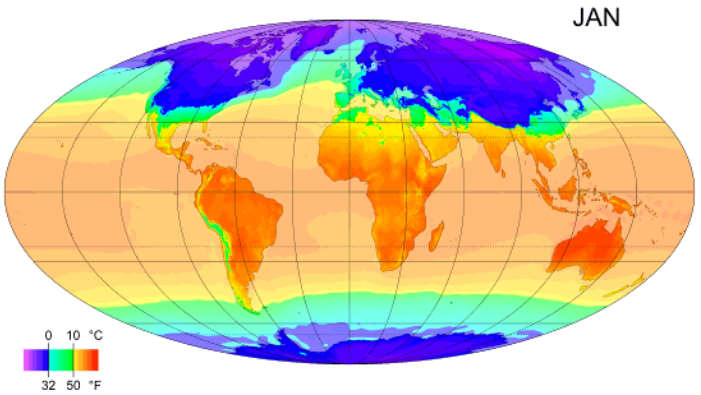
Shaded Area
2/3
66.7%
2:1

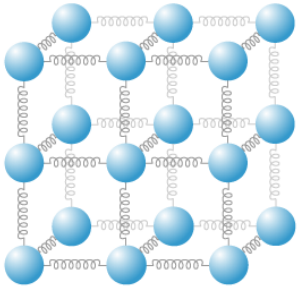
Equivalent Fractions
Improper Fractions

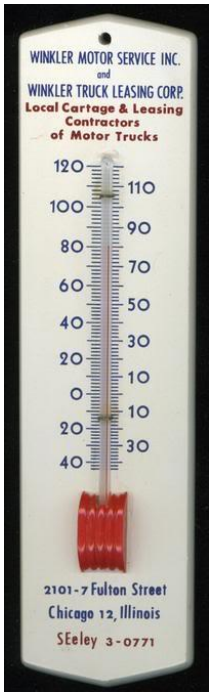
TWO THIRDS

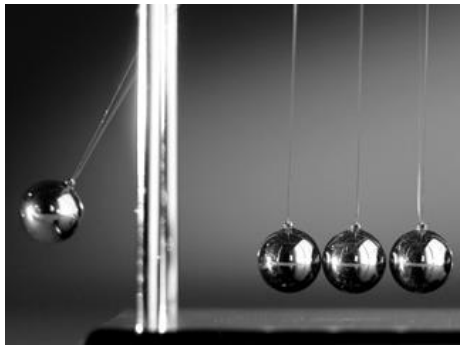
2 ← Numerator
— ← Vinculum
3 ← Denominator

Temperature

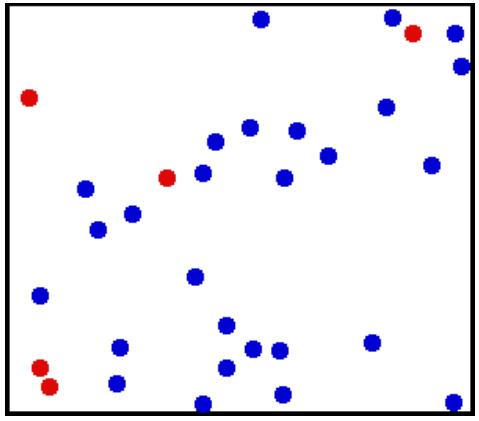






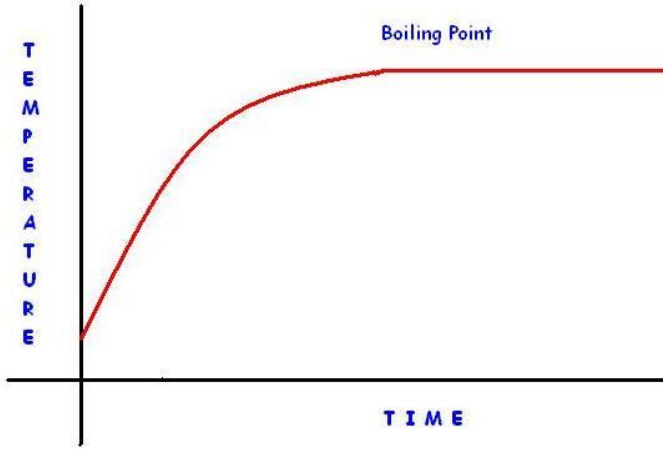


0 K
0˚ C
100˚ C



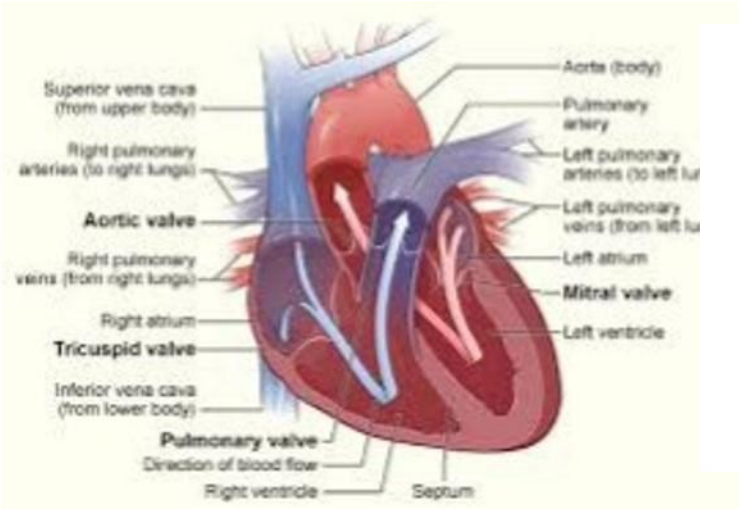
A measure of the average kinetic energy of the particles in a sample of matter

$$KE_{total} = \frac{3}{2}nRT$$

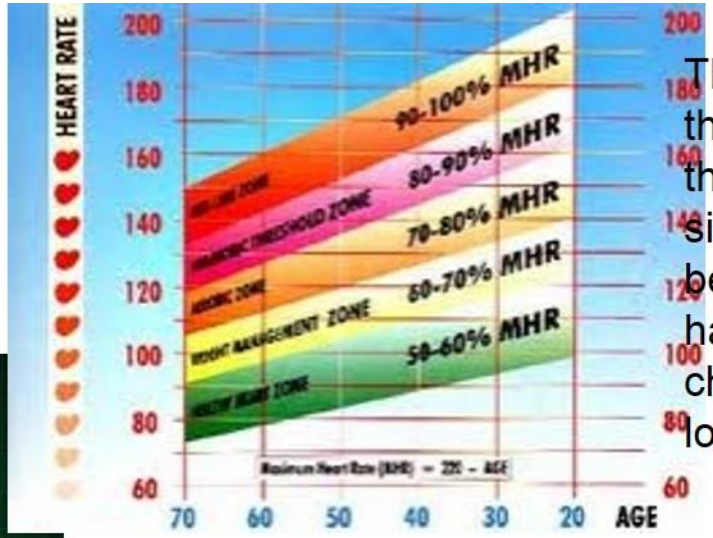


A representation

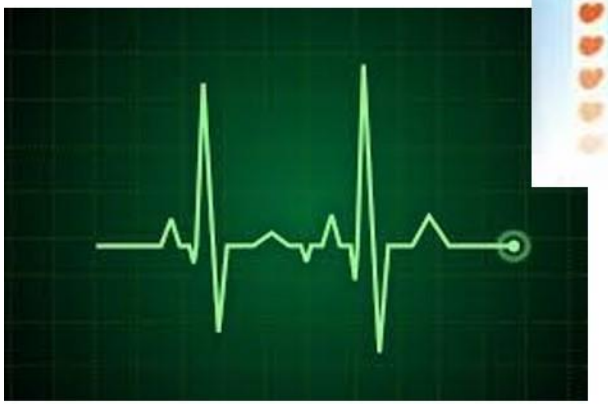
- A representation is something that explains some aspect of nature (the target). It is only partial in its explanatory power.
- Some aspects of the target can be explained by the representation and some aspects of the target can not be explained by the representation.

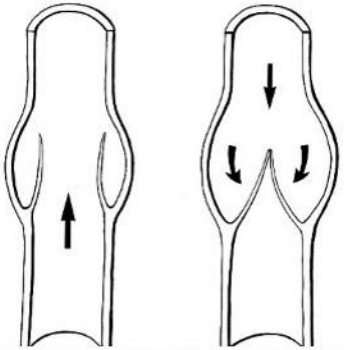


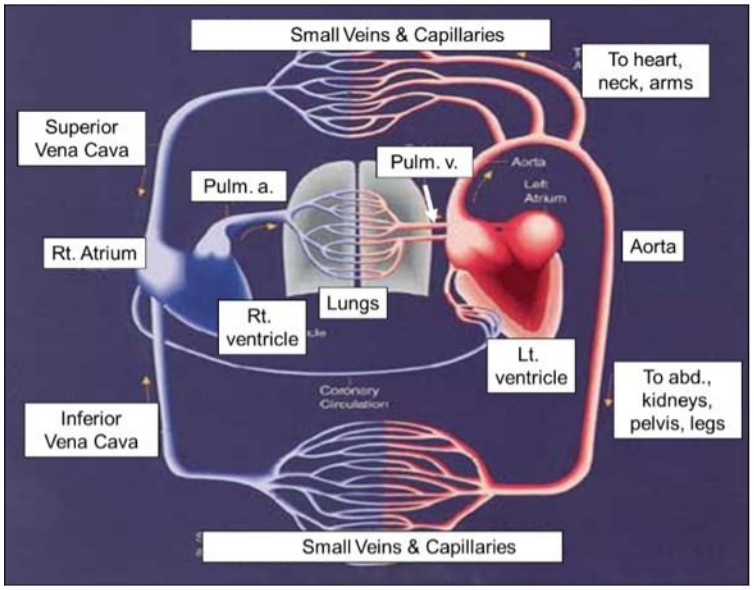
Human Heart

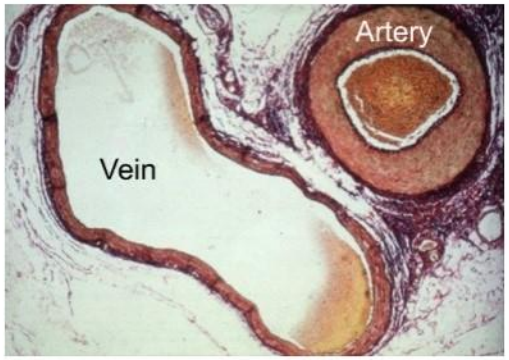


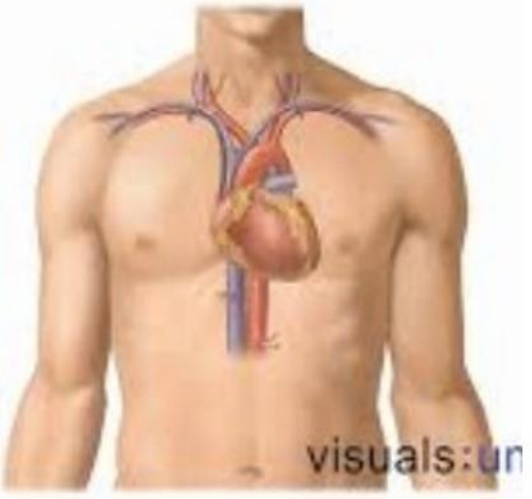
The human heart is an organ that pumps blood throughout the body. It heart is roughly the size of a large fist and weighs between 250 and 350 grams. It has four chambers: two upper chambers (the atria) and two lower ones (the ventricles



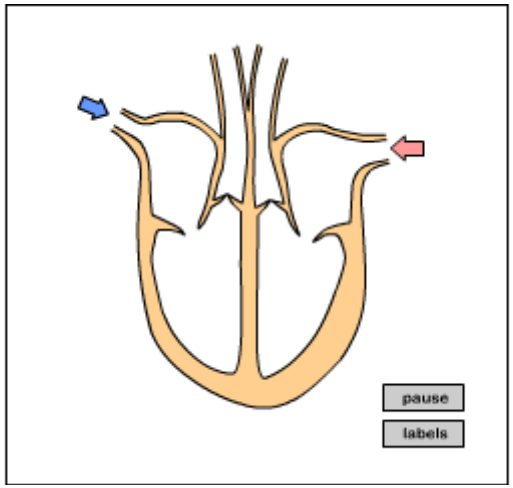


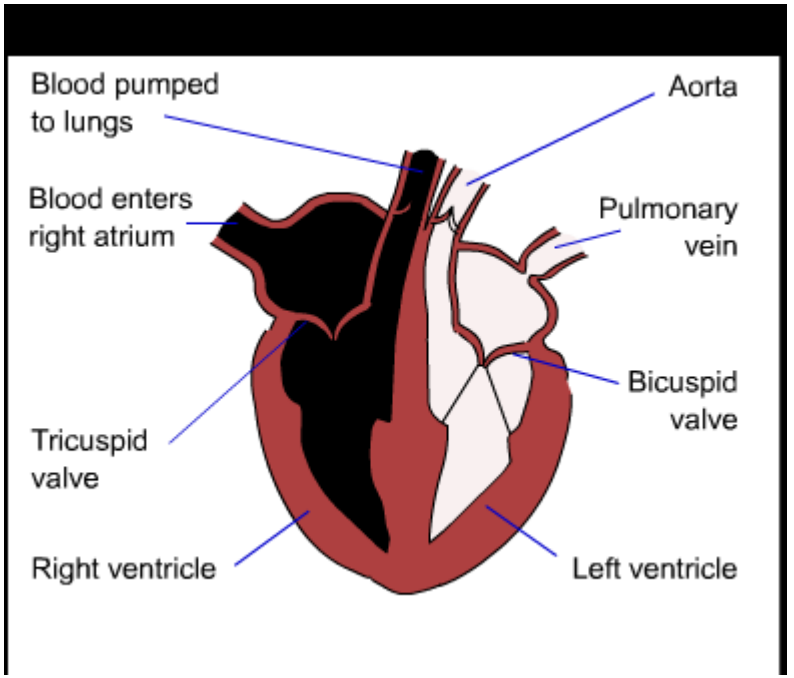


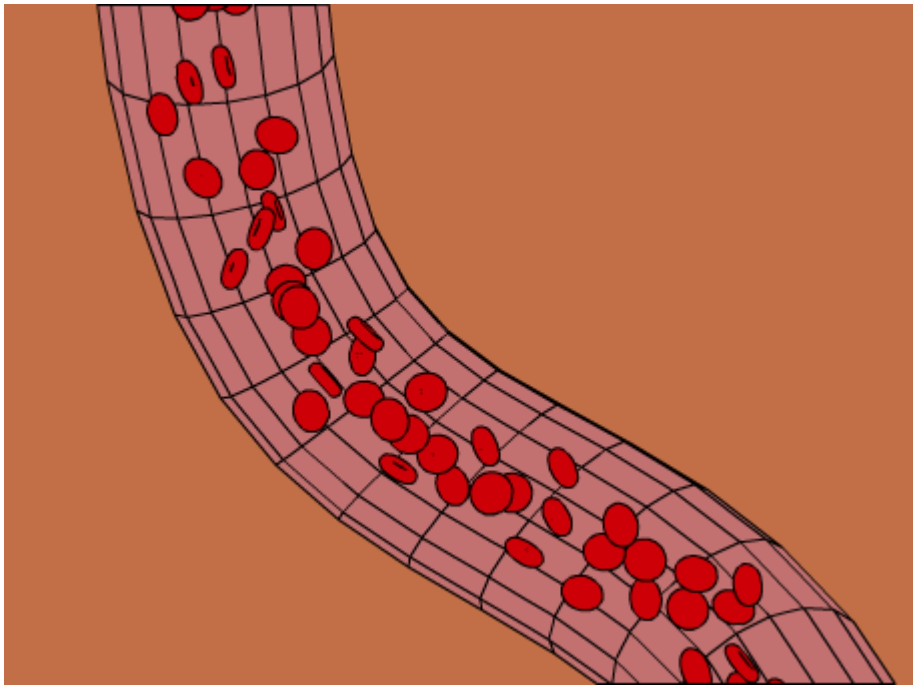




Human Heart


pause
labels

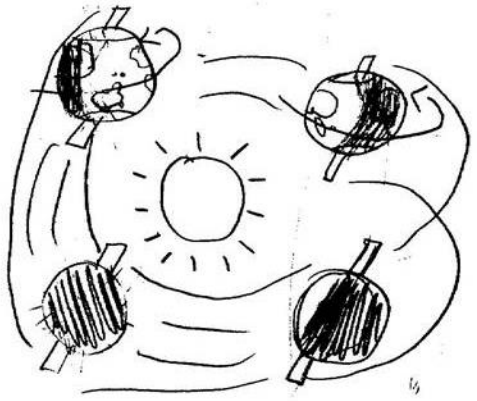

Blood pumped to lungs
Aorta
Blood enters right atrium
Pulmonary vein
Bicuspid valve
Tricuspid valve
Right ventricle
Left ventricle



Introducing Astronomy

Day and night are caused by the Earth turning on its axis
The seasons are caused by the changing angle of the Sun's rays on the Earth's surface at different times during the year

Case study of Year 7/8 Science Classes



The globe as a representation of Earth in space

What aspects of Earth are represented by the Globe?

What aspect of Earth are not represented by the Globe?

The globe as a representation of Earth in space

What does the globe represent	What does the globe not represent
The earth is spherical	It isn't the same size.
It has land regions and ocean regions	You can't see the inside.
The earth rotates	The earths gravitation pull
	The Earths atmosphere.

What does the globe represent?	What does the globe NOT represent?
- The axis that the Earth is tilted on.	- The clouds/atmosphere
- The equator	- The way it spins around the sun.
- The countries and the continents	- Gravity is not represented
- The longitude and latitude lines.	- Earth's location and relation in space
- The shape of the Earth.	- Moon/ the tides
- The Earth has a lot of water.	- The day and night cycle
- The Earth rotates	- The size of the Earth.
	- The inside of the Earth.

Does the globe represent Earth's mountains?

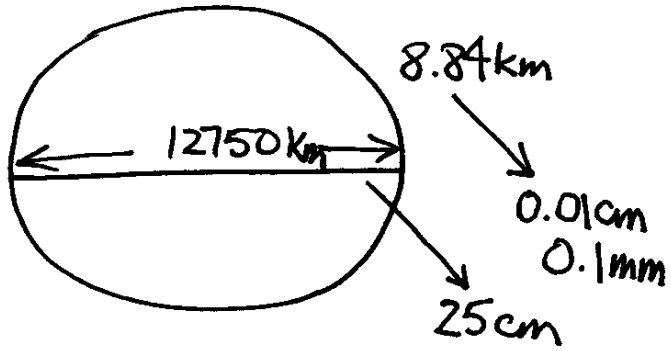
Explicit links were between multiple modes of representation

Visual and haptic explorations of the globe.

Is Mt Everest accurately represented on the globe?

Scaling process.

I want you get out your rulers, see what 0.1 mm looks like.



Representational challenges

You (pair of students) are to construct a role play model, to provide an answer to the following questions:

1. Is it possible for a pair of celestial objects to revolve about each other?
2. The Moon revolves around the Earth every month; one side of the Moon always faces the Earth. Over the period of a month does the Moon undergo any rotation? If so, how many times?

Representational challenges

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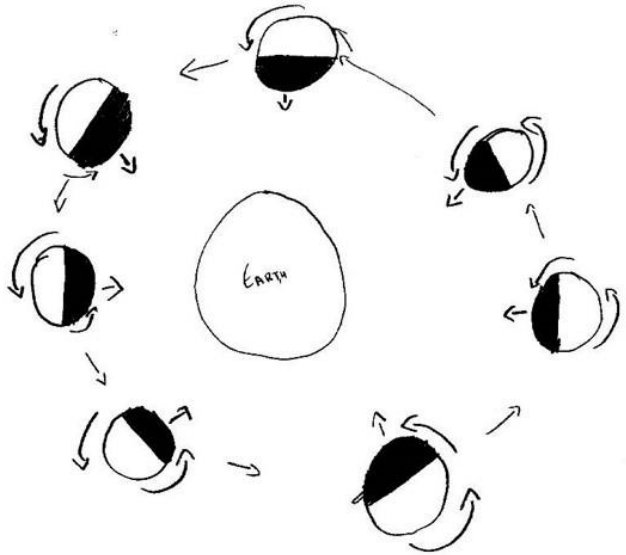
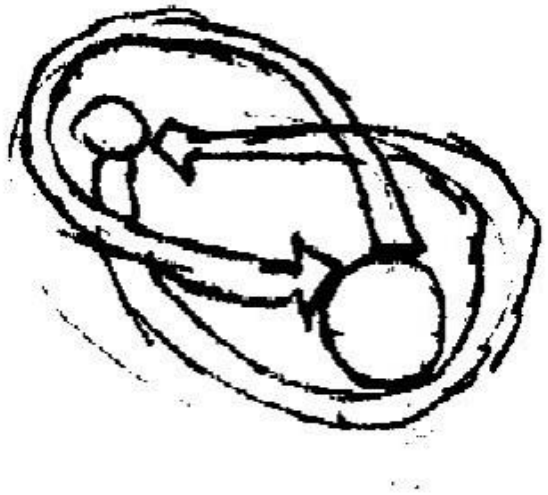
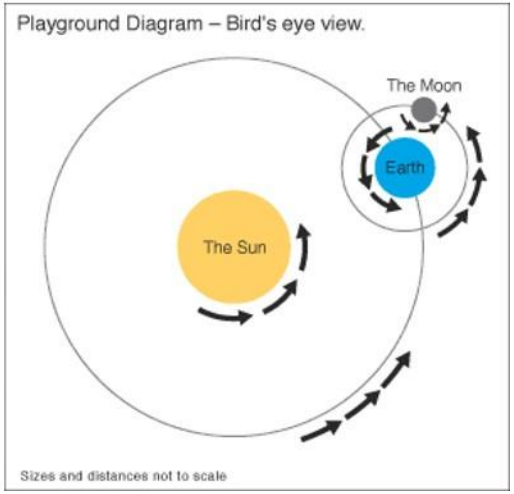


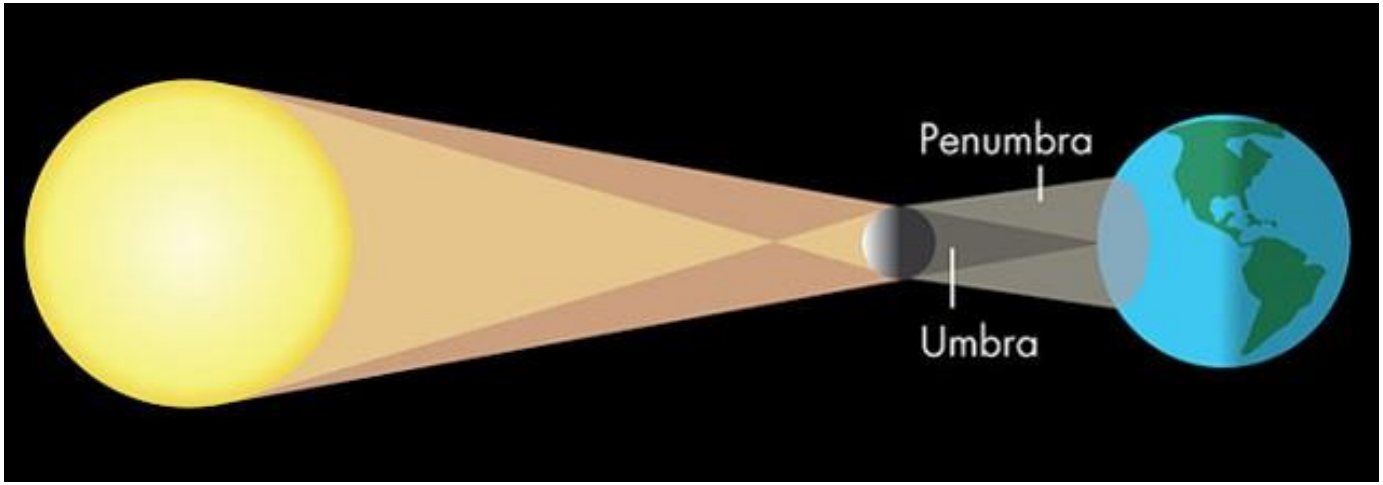


Why don’t we get two eclipses every month?



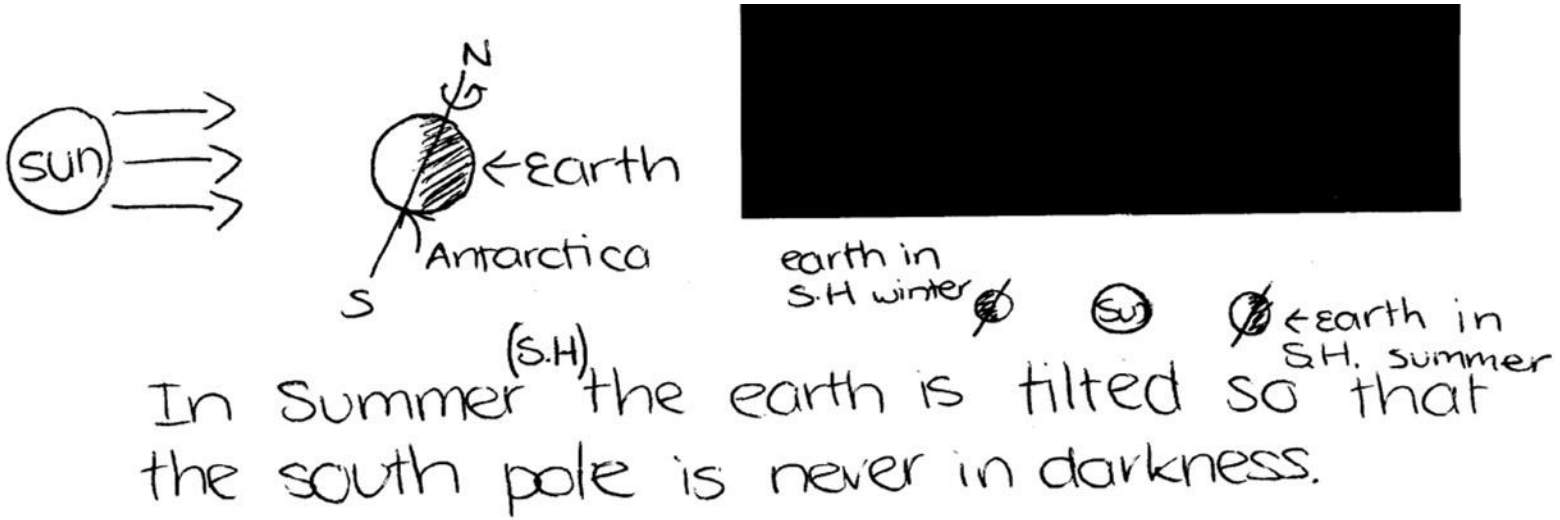
What do these show?

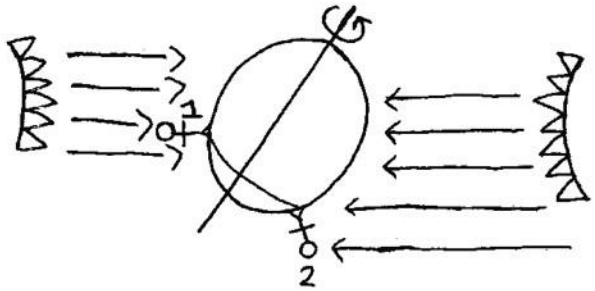
What do they not show?

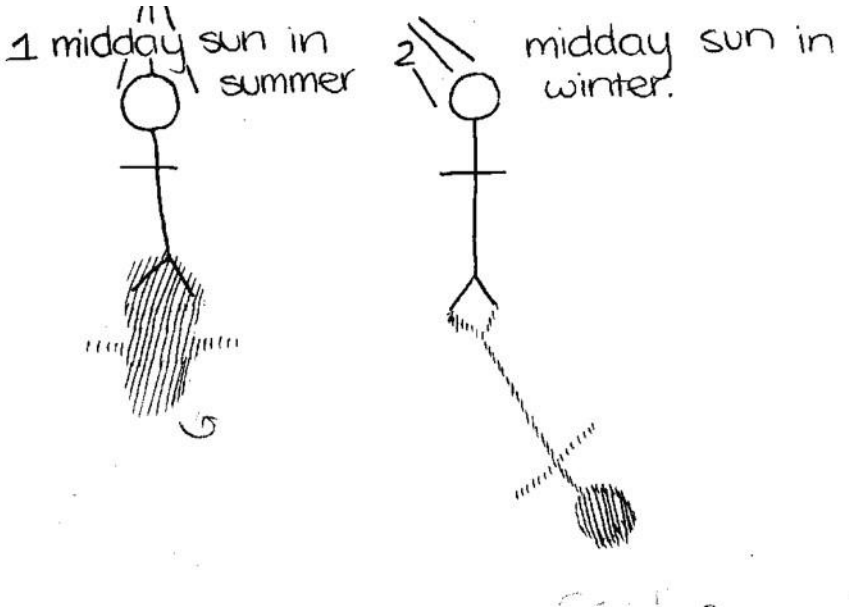


Representational Challenge

Re-represent the image on the right from the perspective of an observer in space.

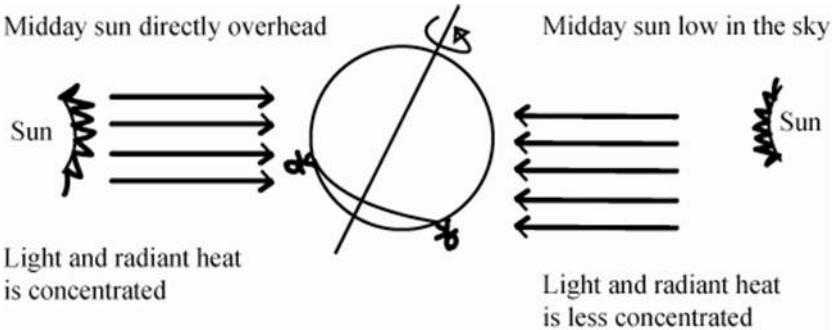






Representational Challenge

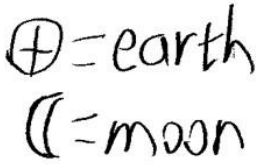
Re-represent the diagram on the right from the perspective of an observer in Melbourne in Summer and Winter



What is it like to live on the Moon?

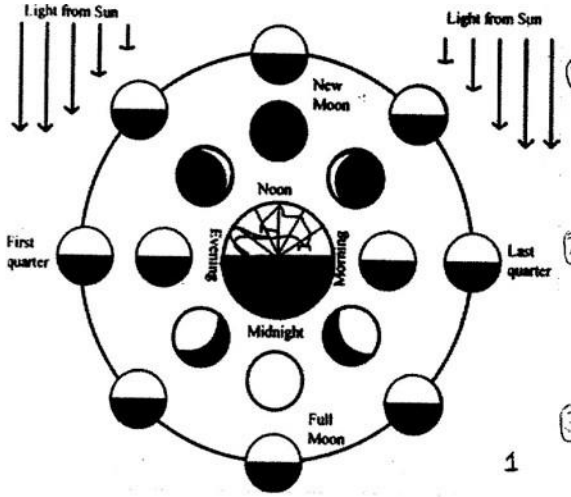
1. Is there day and night? Will the sun rise and set? If so how long is the day/night cycle?
2. Will the Earth go through different phases like the Moon does from Earth? If so how long is this complete cycle?
3. Does the Earth appear bigger in the sky than the full moon does on Earth?

Living on the Moon



Researcher: I was interested in what you did when you wrote 1 moon day equals 1 moon month.
John: yes, that was something I just scribbled down during one lesson…poor Mercury doesn't have a month.
Researcher: why is that?
John: it doesn't have a moon.

Moon phase representations critique



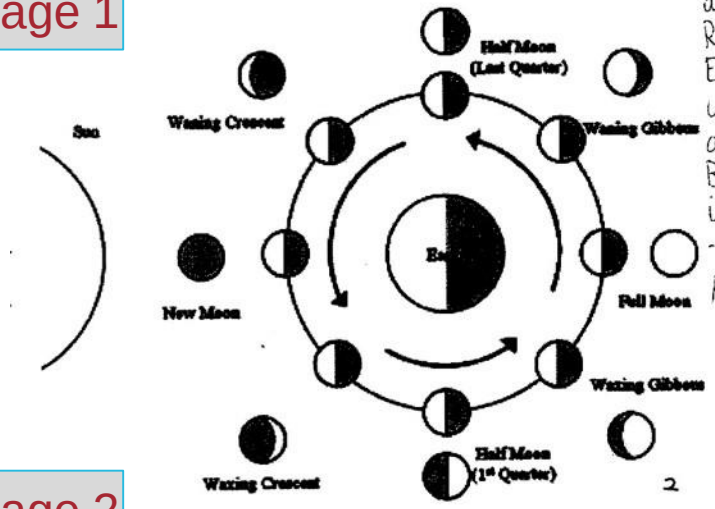
1

① What gives a better representation of the moon's phases? Why?
Image 2 gives a better representation becau
it gives a more detailed representation.

② How do they explain why there are phases of the moon? They show us how the phases are viewed from earth and from outer space, and how they are depicted differently.

③ What are some negatives about these representations? Representation 1 seems to depict that everything is rotating and revolv around earth, and this is incorre Representation 2 shows that the Earth is always facing the sun however, we know that the earth is actually always revolving and rotating Both of these representations need improving, however, give key infor -mation about the moon's phases.

Image 1



2

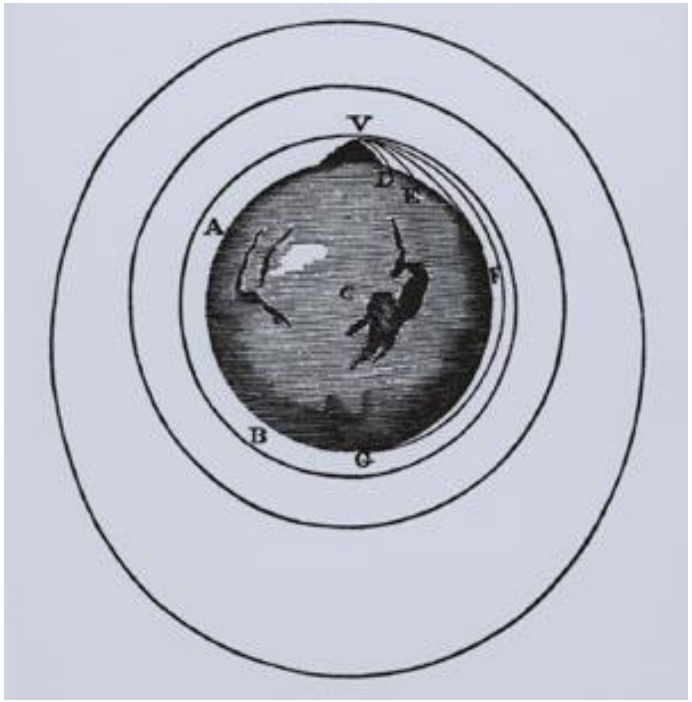
Image 2

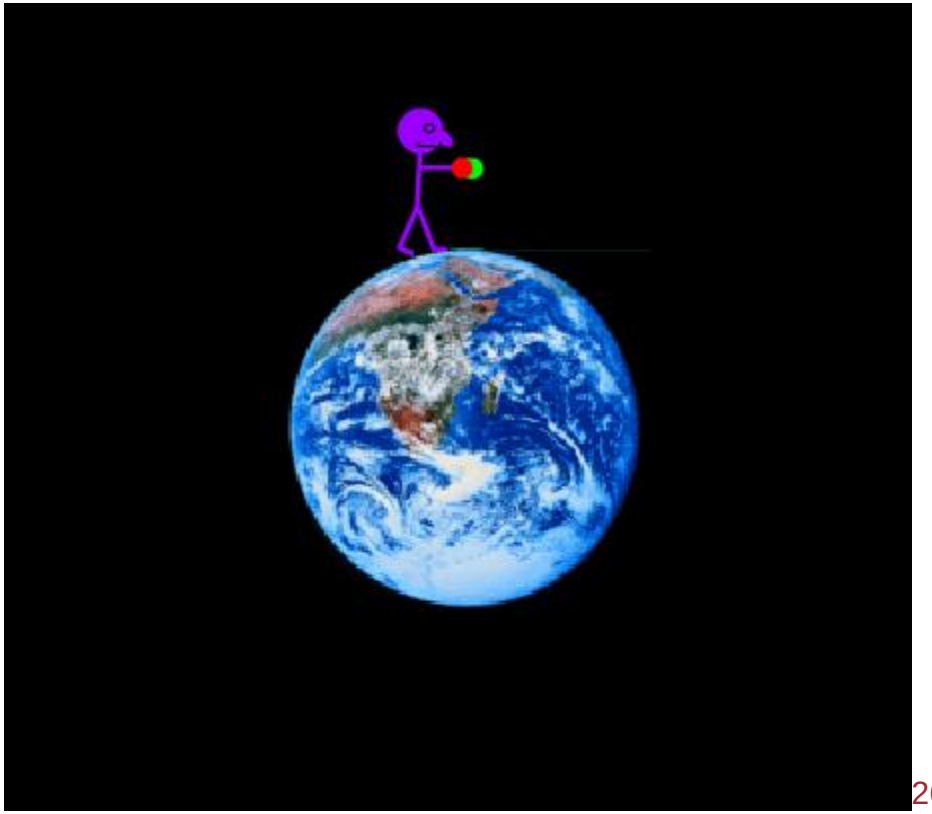
Questions to answer:

1. *What gives a better representation of the moon's phases? Why?*
2. *How do they explain why there are phases of the moon?*
3. *What are some of the negatives about these representations?*

If apples fall to ground because of gravity then why doesn't the Moon?

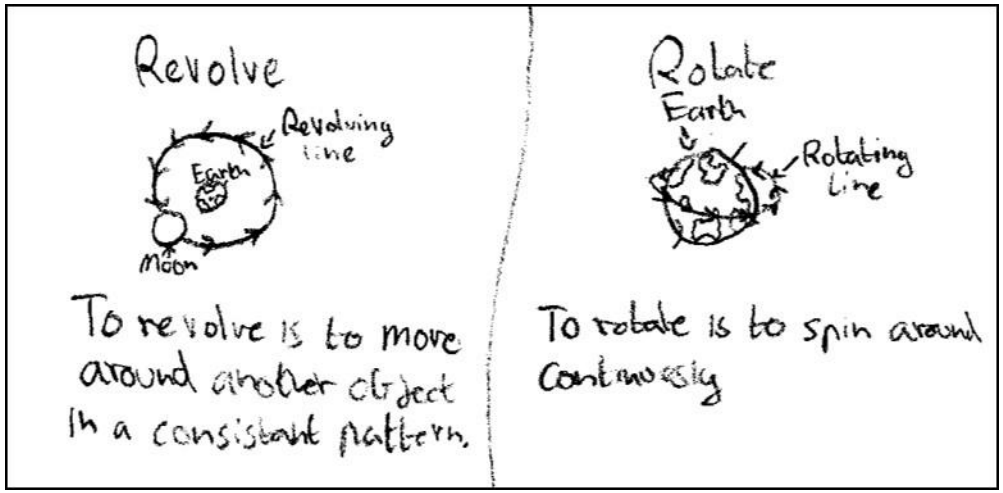
Newton's Cannon Model – Thought Experiment





Rotation and revolution

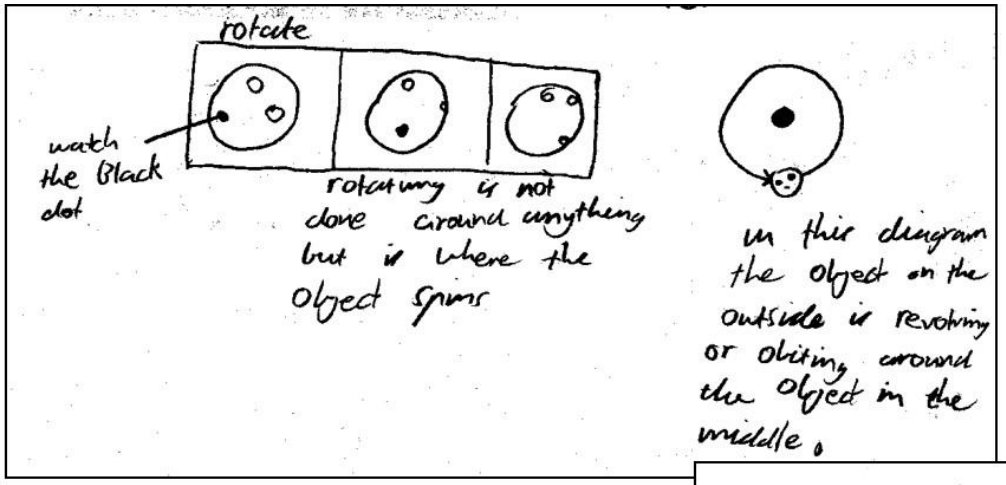
Summative assessment provided opportunities for students to generate and interpret representations.

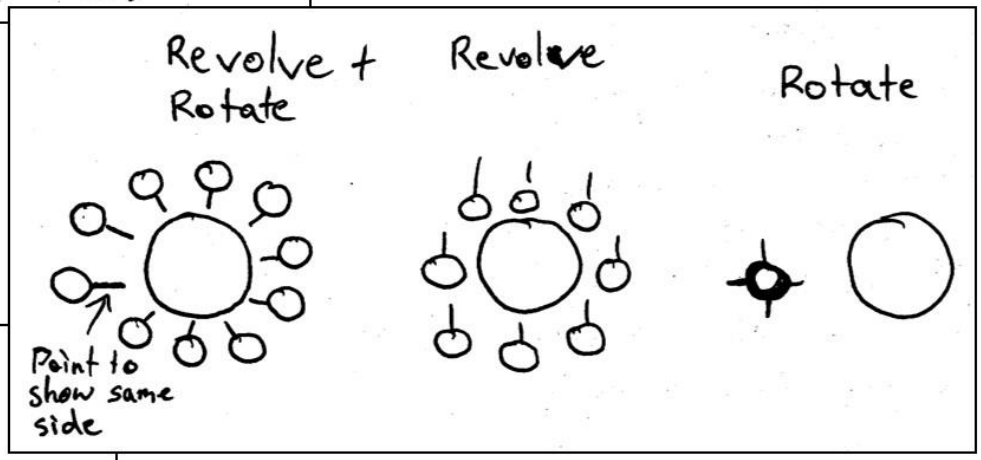


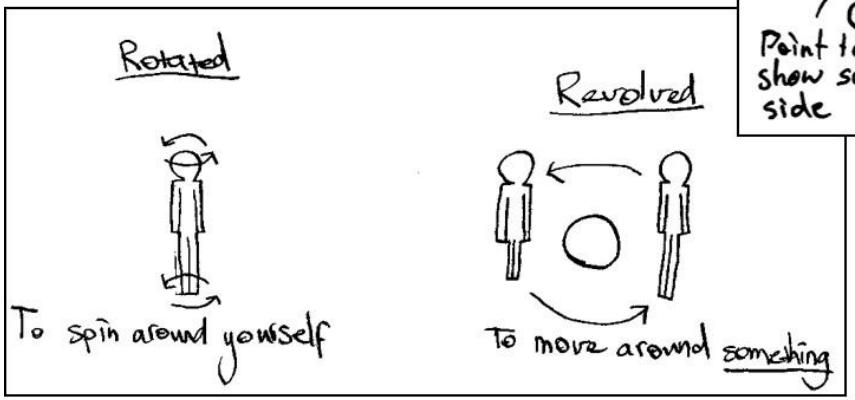
Post-test Question

An astronomer investigating the motion of *Europa*, which is a moon, or natural satellite, of the planet *Jupiter*, found that it *revolved* as well as *rotated*. Use the space below to clearly explain what each of these motions mean

to rotate is to spin. Rotation is done on the spot. To revolve is to orbit or go around something. To revolve you need two objects: one to be revolved around and the other to revolve around the first object. So Europa must spin or rotate at the same time as it orbits or revolves around Jupiter.







The provision of a generous space provided to the students to answer this test question gave them the opportunity, and permission, to generate their own representations.

Model construction

Activity with a strong perceptual context (i.e. hands on, experiential) with two-way mapping between objects and representations.

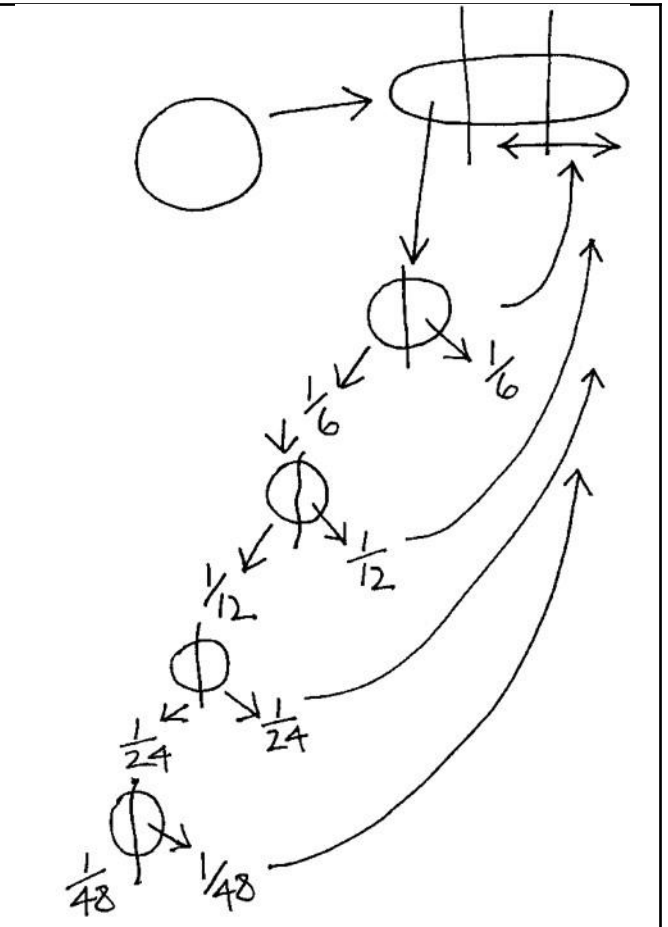
A model construction activity where students constructed plasticine models of the Earth and Moon to their relative sizes and distance separation in two stages:

- Prediction stage
- Accurate construction stage

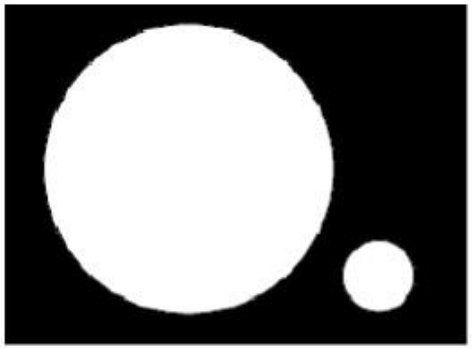
Relative sizes of Earth & Moon

Relative size of Earth and Moon

- Join the two spheres together and roll the plasticine into a sausage shape;
- Divide the sausage shape into three equal parts and then join two of the parts together.
- Divide the third piece of plasticine into two halves, keeping one half in your hands and adding the other half to the larger piece of plasticine.
- Divide the smaller piece into two, keeping one half in your hands and adding the other half to the larger piece of plasticine.
- Repeat step 4
- Repeat step 4
- You should now have one small piece and a large piece. The small piece represents the Moon and the small piece represents the Earth.



Models of the Earth-Moon system



Representation construction approach

1. *Sequencing of representational challenges involving students generating representations to actively explore and make claims about phenomena*
    a. *Clarifying the representational resources underpinning key concepts*
    b. *Establishing a representational need*
    c. *Coordinating / aligning student generated and canonical representations*

2. *Explicitly discussing representations*
    a. *The selective purpose of any representation*
    b. *Group agreement on generative representations*
    c. *Form and function*
    d. *The adequacy of representations*

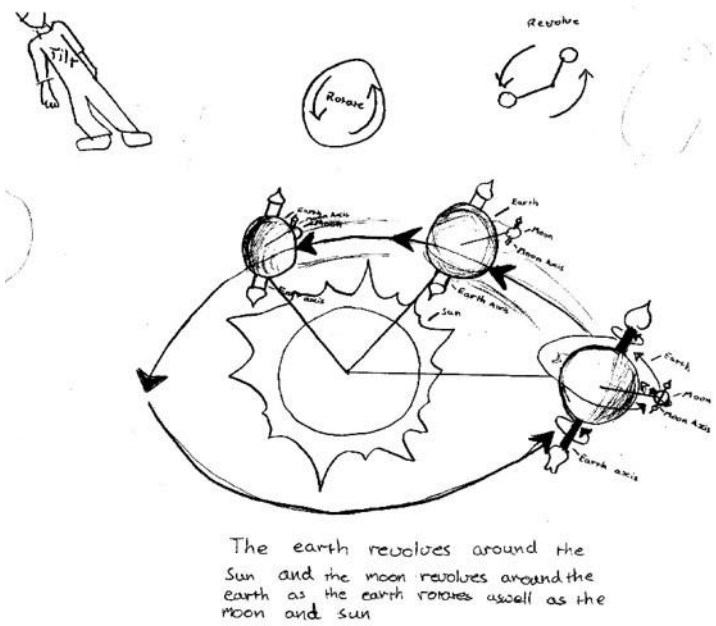
3. *Meaningful learning*
    a. *Perceptual context*
    b. *Engagement / agency*

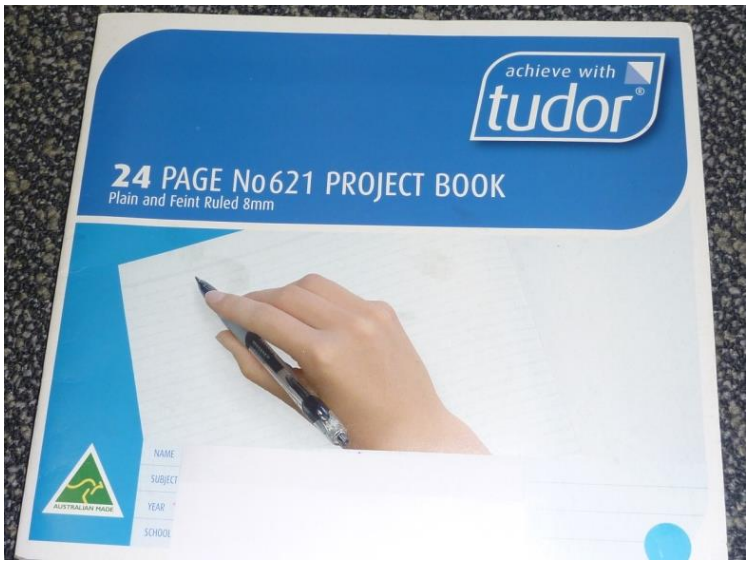
4. *Assessment through representations*

Student learning journals

- Less emphasis on ‘traditional’ note taking
- Workbooks used by the students were treated more like journals.
- More use of annotated drawings as a record of learning

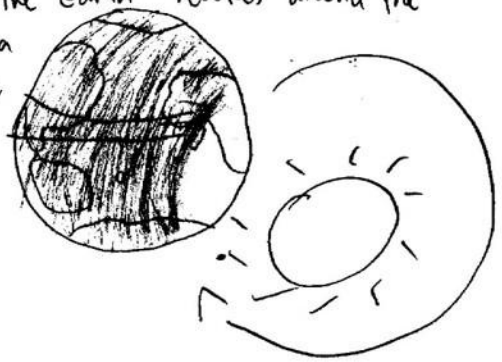
What I learned today – rotation, revolution and tilt





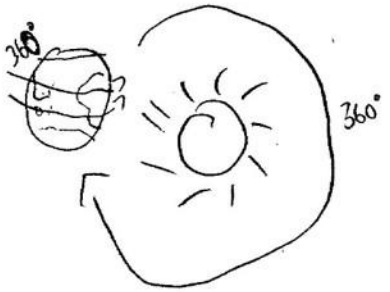
What I learned today – rotation, revolution and tilt

This is representing where the sun hits the Earth. The Arctic isn't getting any sun because of the tilt. The Earth revolves around the Sun on a tilt while rotating on it tilt.



Revolution

revolve around a fixed point

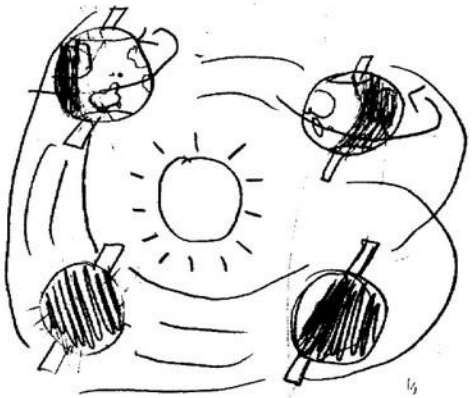


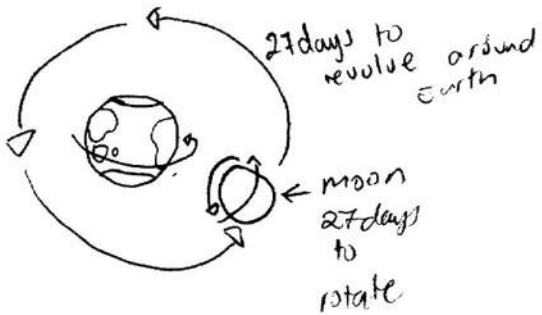
Rotation

rotate around an axis

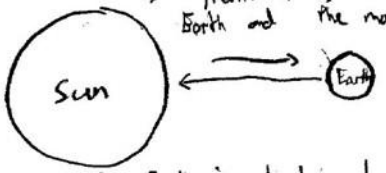
3 things learnt in the clip.

1) The Earth is rotating on it tilting axis.
2) The Earth is revolving around the Sun
3) The Earth doesn't change its tilt

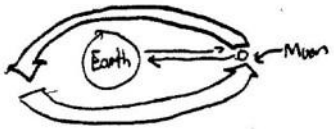


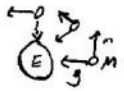


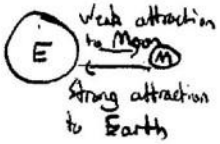
in its pull. This is the same for the Earth and the moon.



The Earth is kept in place by the Sun's gravity.



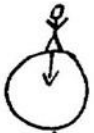




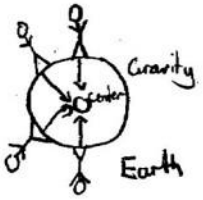
More gravity
Less jump height

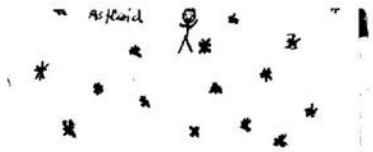
Less gravity
More jump height

Smaller, less dense moon.
Less gravity

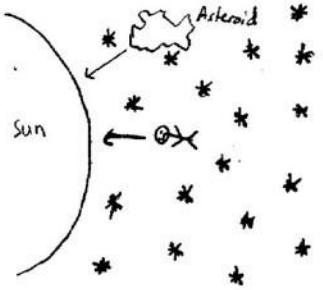


Larger, dense Earth
More gravity

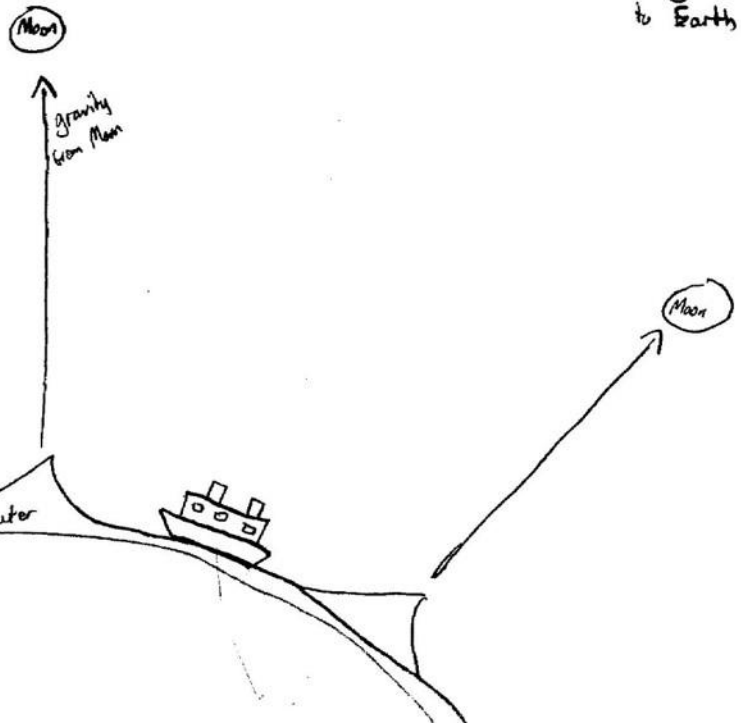




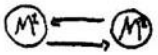
No nearby masses (stars, planets) = no gravity in space



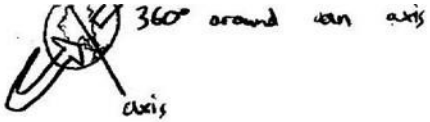
Nearby masses (stars, planets) = gravitational pull



Gravity

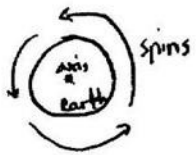


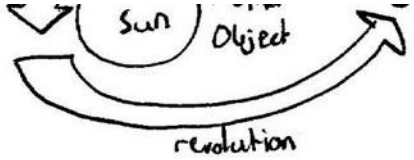
Force that attracts two or more masses together



rotation

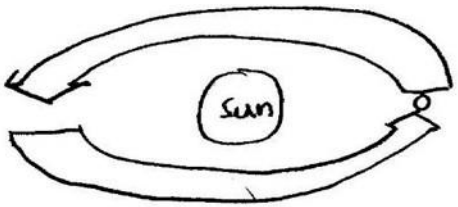
Birds-eye



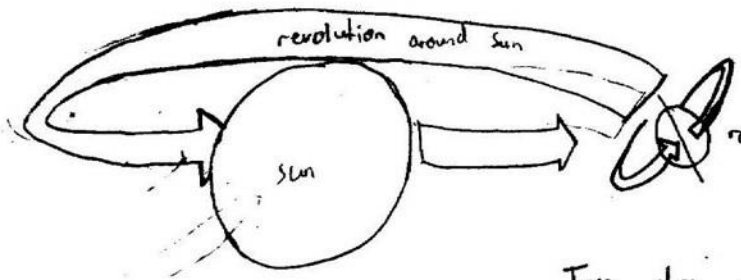


revolution

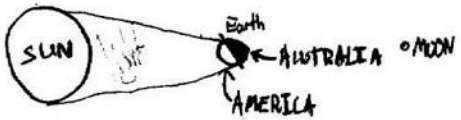
Birds-eye



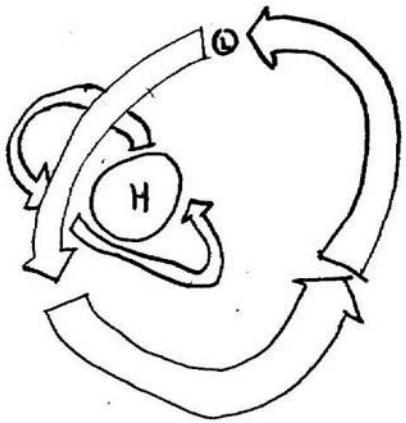
Australian Seasons



Two stars revolving

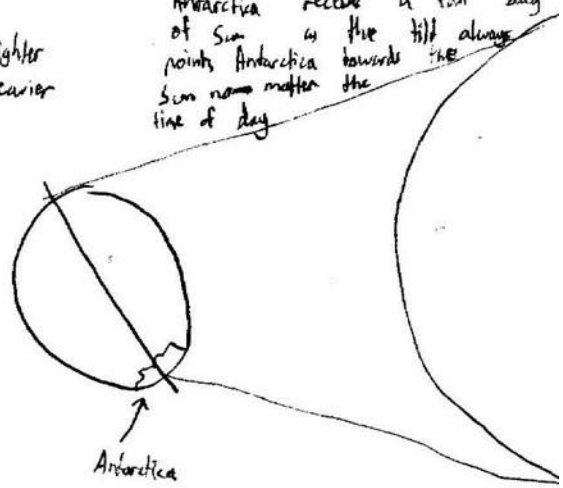


Earth rotates the cities in and out of the sunlight
Every time it rotates to its original position, the cycle restarts and a new day begins in a city.



L = lighter
H = heavier

Due to the Earth's tilt, when in the time of their year the axis is pointing away from the sun, Antarctica receive a full day of Sun as the tilt always points Antarctica towards the Sun no matter the time of day



Student learning journals

- Seen by teachers as a useful formative assessment tool
  - *Immediately by looking at their representations, know, okay those boys have got it and those boys are on the right track but those haven't fully kind of understood.*
- Students were more willing to use their journals to reflect on their learning
  - *…they seemed more willing to go back over their work and look back at their past stuff as well…And I don't think they do it very well if it's just written stuff and they had a sense of ownership over it which was good.*
  - *They loved their project books. Like ridiculously…. it was like this little diary of all the work that they'd done. It was different from what they had been doing.*

A Problem

$$4 + 2x3 =$$

Three friends are hungry and decide to buy coke and chips

Scenario 1

Each buys a can of coke.
The whole group shares one bag of chips

Can of Coke
$2

Scenario 2

Each buys a can of coke and a bag of chips

Bag of Chips
$4

Representational Challenge

Write a mathematical statement, or statements, that give the total cost for each scenario.

Paving square garden borders

Pavers are 1 sq. m

How many pavers are required for a square garden 1 m in length? What about 2 m? 5 m?

Use the square paper to work out your answers.

Can you find the answer to any sized square garden without using the square paper?

How expensive is a dripping tap?

Sub Questions	Avenues to Solution
What does water cost?	Internet search. Home water bill.
How much water is in a droplet?	Creation of a model: pipette and measuring cylinder.
Do different taps create different sized droplets?	Investigation that involves collecting droplets from different taps around the school – increase accuracy through multiple trials that collect, say, 50 droplets at a time.
Depends on the drip rate: What is the slowest rate of drip? What is the highest (ie before it becomes a stream)?	Science/STEM room investigation with tap.
Are all droplets the same volume?	Taking mass measurements knowing that 1 ml = 1 g (for water) rather than volume measurements.
What is the relationship between volume of water and its mass?	Investigation – tabulation of results, graphical representation, formula?
What is the relationship between the drip rate and volume of water? What is the relationship between the drip rate and cost of water for a month?	
Why does water form a droplet?	Exploration of properties of water (science class) – surface tension being the key concept.