Notes for teachers

An introduction to climate modelling

This activity presents basic ideas about the Earth's climate and the greenhouse effect, and how a simple model can allow us to understand how the Earth's temperature may be determined.

There are three parts:

- An introduction to the greenhouse effect and to scientific modelling (using powerpoint or overhead transparencies)
- A practical activity
- A computer based activity (using an Excel spreadsheet)

The activities are designed for science lessons in Year 9 (or 10, 11) (pupils aged 13-16).

Part 1

KS34intro.pdf

This presentation introduces the greenhouse effect and how a model can be used to represent it.

Throughout the presentation, questions are posed and there is an opportunity to stop and spend time thinking and discussing points raised.

Slide	Pupil activity	Notes	Approx time
1	Objectives for first half		
2	Identify clouds, land masses and oceans. Consider what might happen to the radiation arriving from the Sun.	Pupils should think about: absorption by oceans, land and atmosphere; reflection from clouds and land. Relate absorption, reflection, emission to light and dark areas.	5-10mins
3	To compare their ideas with the actual situation	Discuss what the figures might mean for the temperature of the Earth and atmosphere	2mins
4	Extend the ideas to include the greenhouse effect.	Arrive at the idea that because the Earth radiates energy, some of which is reabsorbed, the Earth stays warm. The rate of arrival of radiation = rate of loss of energy.	2mins
5	Consider why an understanding of temperature is important. How might people's lives be affected by changes in climate?	Broaden this beyond pupils' local perspective and think about global issues e.g. effects on people in low lying areas (Tuvalu, Bangladesh) or those in drought-affected areas.	10mins

6	Objectives for second half		
7	General ideas about models in science.	A quick activity to relate the pupils' understanding of the word model to how scientists think of it	2 mins
8-9	Understand the tank model, and predict what will happen in different situations.	Pupils could work in groups to identify variables and how they might go about testing certain hypotheses. This could relate to the dependence of pressure on depth.	5-15 mins
10-11	Relate the model to the situation of the Earth and Sun discussed earlier	An equilibrium will be reached; altering the rate of flow from the tap, or the size of the outlet, will alter the equilibrium depth.	10mins

After slide 11, you could revisit slides 4 and 5 to end with a plenary on the Greenhouse effect.

Here is a way to demonstrate the model. A large plastic lemonade bottle with two 2mm radius holes in the bottom suspended over a sink, with a rubber tube from the tap into the top is needed.

With both holes open and water falling out, this represents the Earth radiating heat. When the tap is open, it should be possible to reach a stable state. Then if one hole is covered up, you can simulate what happens with extra CO_2. The emptying rate falls and the water level should rise until another stable state is reached.

Part 2

bottle_practical_worksheet.pdf

This is an optional practical lesson that asks pupils to show that there is a relationship between the rate at which water leaves the bucket or bottle and the height of the water. It relates to the climate by saying if the Earth is hotter, it radiates faster to space. It can be completed in one hour, or extended as a more open ended investigation.

The speed v of water leaving the hole is related to the height H by $v^2 = 2g\mathrm{H}$. The horizontal distance, X, the water travels is proportional to v. (In fact, $v^2 = g\mathrm{X}^2/2\mathrm{Y}$, where Y is the vertical distance between the tube and the horizontal ruler. Hence Y should be made as big as possible.)

The practical won't quite match the theory because

- flow will stop before H = 0 cm. This is because the surface tension inside the thin tube is enough to compensate for the pressure due to the liquid.

- Viscosity (friction at the walls of the tube) and turbulence in the tube cause energy losses

The equation relating v and H is more like $v^2 = 2g(\text{H-R})$ where R is a constant.

(see PMC de Oliveira *et al*., Pin-hole water flow from cylindrical bottles, Phys. Educ**.** **35**(2) March 2000).

Part 3

Bucket model.xls

This is a computer based activity that should take approximately 30mins, but could take longer depending on the ability of the group.

Pupils are asked to complete a spreadsheet of results from the bucket model. Some complex mathematical expressions are not gone into in great detail. It is the teacher's choice how much of this they wish to explain, depending on the group.

When the results are generated by the spreadsheet, pupils should plot a graph of height against time and see that a stable situation will be reached.

Time will be needed at the start to demonstrate the experiment or recap from the previous lesson if pupils carried out or saw the experiment relating height to rate of flow. Time should be left at the end to revisit the application of the model, namely the greenhouse effect and the stable temperature that will be reached.

How the spreadsheet works

We have:

g = acceleration due to gravity

h = height

r = radius of hole

Velocity of water out, $v = \sqrt{2gh}$

Volume rate of flow of water out, $V = \sqrt{2gh} \times \pi r^2$

Assuming a hole of radius 0.2 cm and converting all units to cm, $V = 5.6 \times \sqrt{h}$. This goes in column C.

Column D assumes we add 10 ml of water every second.

Column E works out the net change in water volume in 10 s (to make the numbers nicer).

Column F assumes an area of 80cm^2 and then calculates a new height depending on how much water has gone.

This result is then used in the second row as the height after 10 seconds.

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