Science Unit: ***Climate Change***

Lesson 3: ***Earth Energy Budget Pre-lab***

School year:	2008/2009
Developed for:	Shaughnessy Elementary School, Vancouver School District
Developed by:	Tom-Pierre Frappé(scientist), Carol Church and Sharlene Steele (teachers)
Grade level:	Presented to grades 5 - 7; appropriate for grades 4 to 7 with age appropriate modifications.
Duration of lesson:	1 hour and 10 minutes
Notes:	Lesson 3 of a 4 lessons series. This is more a discussion and brainstorm session than an experiment. This lesson is to be used in conjunction with the Excel spreadsheet of the same title.

Objectives

1. Review the basic energy budget of the Earth, including the role of clouds and ground albedo.
2. Gain familiarity with data processing and interpretation, and see how spreadsheets can be used to graph and analyze data.
3. Appreciate why it is necessary to do more than one experiment before reaching a conclusion
4. Practice brainstorming to design a new experiment

Background Information

“The earth's atmospheric "greenhouse effect" is much more complex than the simple greenhouse experiment described in [lesson 1]. While the earth's temperature is dependent upon the greenhouse-like action of the atmosphere, the amount of heating and cooling are strongly influenced by several factors.

The type of surface that sunlight first encounters is the most important factor. Forests, grasslands, ocean surfaces, ice caps, deserts, and cities all absorb, reflect, and radiate radiation differently. Sunlight falling on a white glacier surface strongly reflects back into space, resulting in minimal heating of the surface and lower atmosphere. Sunlight falling on a dark desert soil is strongly absorbed, on the other hand, and contributes to significant heating of the surface and lower atmosphere. Cloud cover also affects greenhouse warming by both reducing the amount of solar radiation reaching the earth's surface and by reducing the amount of radiation energy emitted into space.

*Scientists use the term **albedo** to define the percentage of solar energy reflected back by a surface. Understanding local, regional, and global albedo effects is critical to predicting global climate change.* [1]*”*

The following are some of the factors that influence the earth's [energy budget].

- ***Clouds:*** *On a hot, sunny day, we usually welcome a big fluffy cumulus cloud passing overhead because we feel cooler immediately. That's because the top of the cloud reflects sunlight back into space before it ever reaches earth. Depending on their altitude and optical properties, clouds either cool or warm the earth. Large, thick, relatively low-altitude clouds, such as cumulus and cumulonimbus, reflect incoming solar radiation and thereby reduce warming of the surface. The whitewash on plant greenhouses has the same effect on a smaller scale. High-altitude, thinner clouds, such as cirrus clouds, absorb longwave radiation reflected from the earth's surface, causing increased warming.*

Cirrus *Cumulus* *Nimbus*

- ***Surface albedo:*** *Just as some clouds reflect solar energy into space, so do light-colored land surfaces. This surface albedo effect strongly influences the absorption of sunlight. Snow and ice cover are highly reflective, as are light-colored deserts. Large expanses of reflective surfaces can significantly reduce solar warming. Dark-colored land surfaces, in contrast, are strongly absorptive and contribute to warming. If global temperatures increase, snow and ice cover may shrink. The exposed darker surfaces underneath may absorb more solar radiation, causing further warming. The magnitude of the effect is currently a matter of serious scientific study and debate.*[1]*"*

Materials

- A computer with projector

In the Classroom

Introductory Discussion

1. In the last lesson, we explored the main factors contributing to the energy balance of the Earth: greenhouse gases concentration, cloud coverage, and ground albedo. The lesson before that, we used a pop-bottle to simulate a basic greenhouse. Today, we will review and discuss the results of this experiment. How can we make sense of the data you collected? How can we compare the varied results obtained by different teams? And finally, what are the differences between this simple model and what happens on Earth? This discussion will help you in your next project: Design a bran new experiment by improving the pop-bottle model and using it to test one of the factor contributing to the Earth energy balance.

Science Activity

Activity Title: Pop-bottle science: Data analysis and experimental design

Purpose of Activity: Discuss with students how the class' results from the first pop-bottle experiment can be analyzed, and how having many experiments is more informative than only one. Use this as a base for them to design a new pop-bottle experiment to test the effect of one of these factors: water vapor concentration, CO2 concentration, ground conver albedo, and clouds.

Experimental Observations: The compiled data from the first pop-bottle experiment is plotted in excel (see spreadsheet attached) and students are asked to comment.

Methods and Instructions:

1. Show students the graph of temperature Vs time for their bottle and control data (in spreadsheet: sheet "graph"). Present the axis, and explain the legend.
2. What do you notice? What strikes you? … It will vary with the data, of course. On the data from our experiments, which are included in the spreadsheet, there are a few noteworthy points:
    a. There is a series that is much colder than all the rest. How is it possible?... it turns out their thermometer was broken! We wouldn't have known it if we didn't have more results to compare with.
    b. There is a wide variation in final temperatures. What factors can explain this difference? [lamps being closer of further away, proximity to windows, drafts, sources of heat, etc.]
    c. The control temperature didn't vary as much as the test temperature.
    d. Generally, the temperature in the bottle is higher than the temperature outside. But is it always the case? At least one test series is colder than other control series (table 2). How is that possible? Does that invalidate our hypothesis? [The test for table 2 is colder than some other control, but it was still warmer than its own control. Table 2 had a "cold bias" but still the effect of the bottle was to warm up the air inside. So hypothesis still holds.]
    e. How could we make this graph easier to read? What are we really interested in? Do we want to know which table was the hottest? [Well, that's interesting, but it doesn't help us test our hypothesis]. What was our hypothesis? [the effect of the pop-bottle, or how much warmer it would get compared to the control… so, for each table, we could plot only the "greenhouse effect", ie, the difference between the test and the control. The tab "graph – difference" in the spreadsheet does that.]
3. Now looking at the "Greenhouse effect" plot (tab "graph – difference" in the spreadsheet), what do you notice?
    a. Still some variation but it is now clear that the temperature inside the bottle was warmer than outside. This verifies our hypothesis.
    b. Some tables started with the bottle already warmer, some with the bottle cooler. There are some other factors at play that we don't understand fully.
    c. What could explain the different efficiency of the different greenhouses? [some had water droplets in them… evaporating them will take some energy thus cooling the bottle. However, once evaporated, there is more water vapor, which is a greenhouse gas that could warm up the air. This could have cooled or warmed some of the bottles. Other possible factors: distance to the lamp, holes at the bottom, drafts, etc.]

Discussion

Now that you have practice analyzing test and control data, you will design your own experiment. Each team of 2 will have 2 pop-bottles, to test one of these factors affecting the energy balance of the Earth:

CO2 concentration
H2O concentration
ground albedo
Effect of clouds

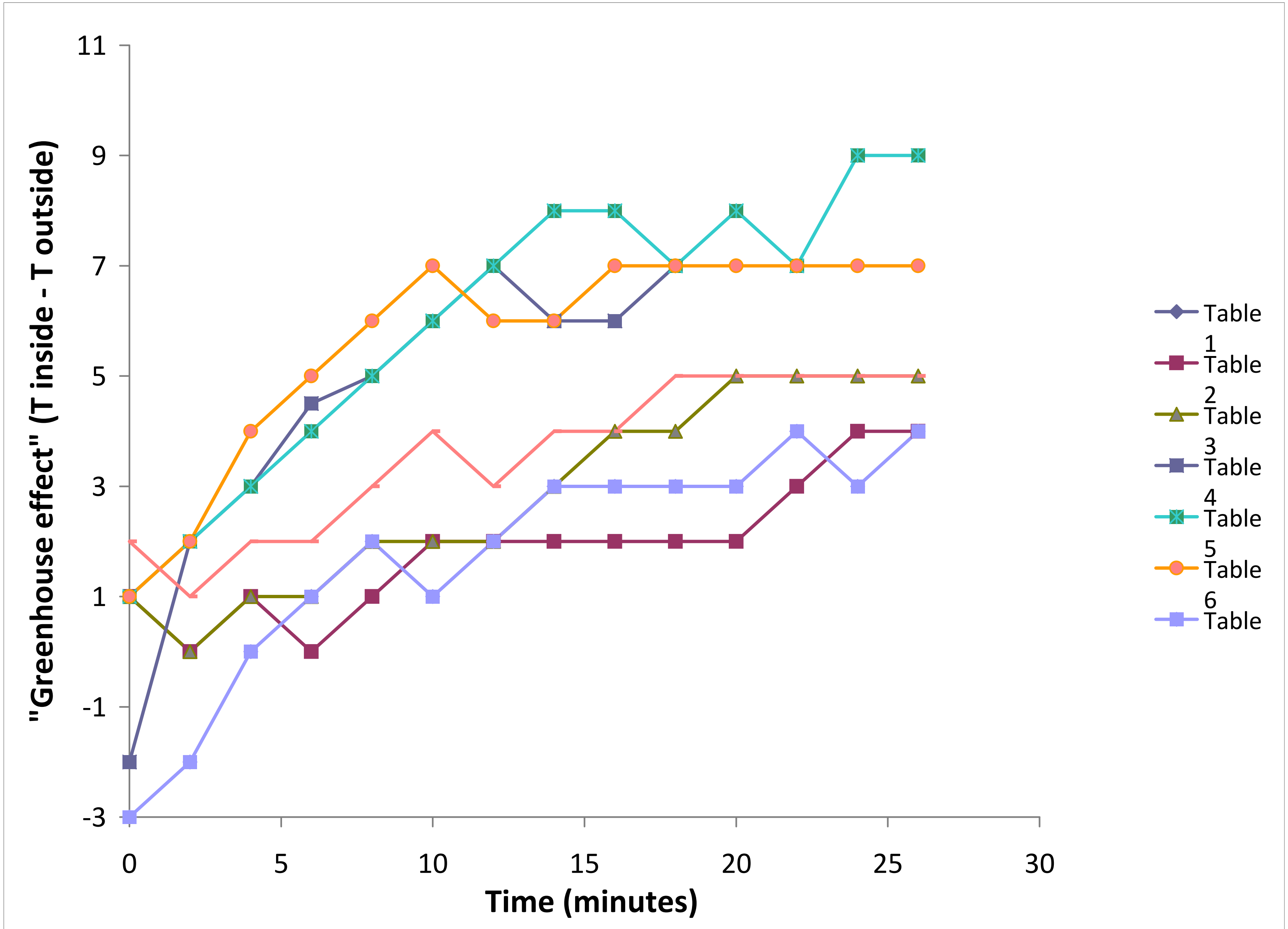
You get to decide what your test bottle will be like, and what your control bottle will be like. Rest of the period used to brainstorm, and answer individual question. At the end, each team reports to the group what they plan to do, and teachers give feedback if needed.

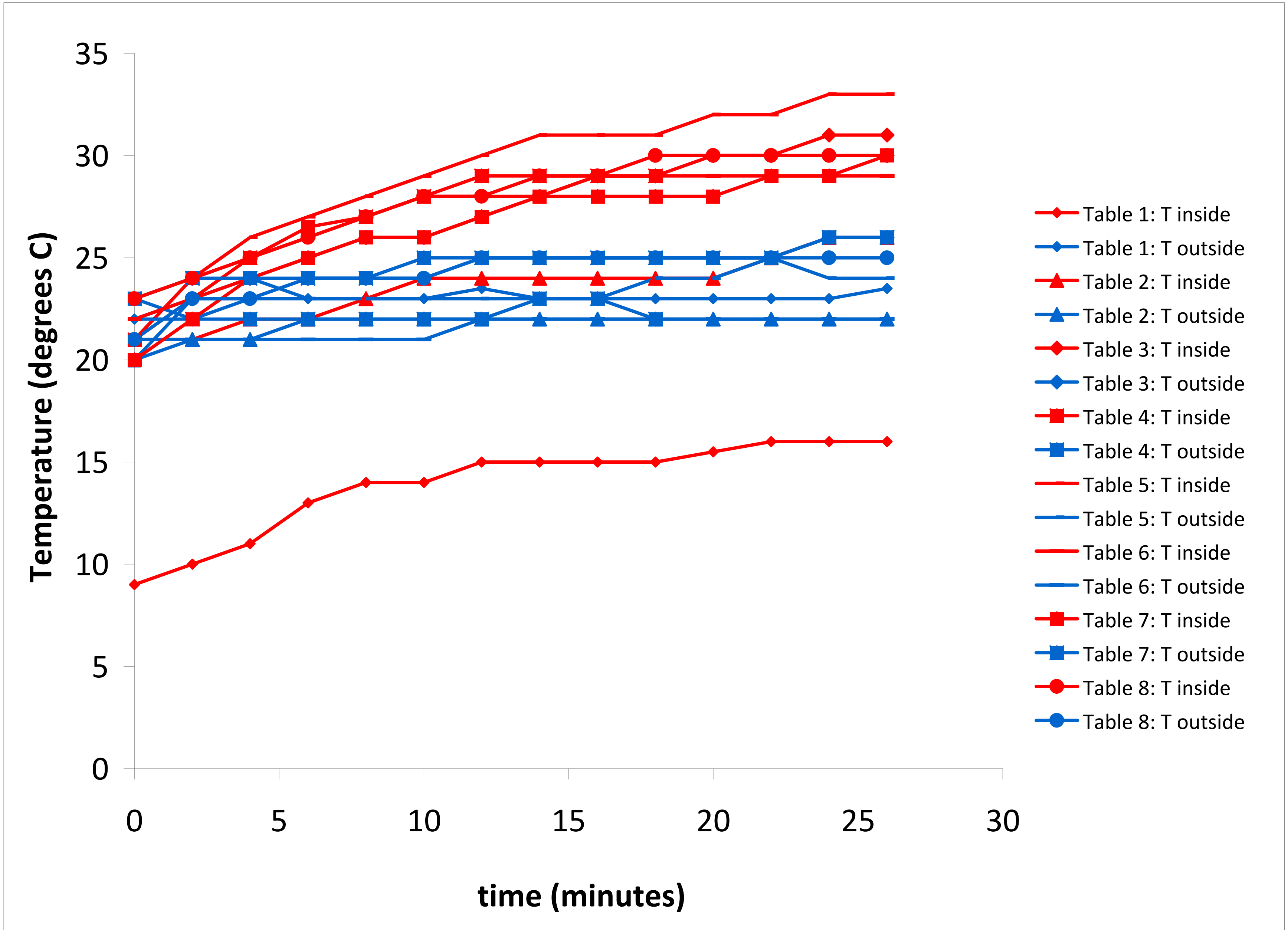
Extension of Lesson Plan

Climate Change science unit, Lesson 4: Student will run their experiment, and analyze the results together.

team:	time	Table 1:			Table 2:			Table 3:			Table 4:		
	time	T inside	T outside	Table 1	T inside	T outside	Table 2	T inside	T outside	Table 3	T inside	T outside	Table 4
	0	9	22	-13	21	20	1	21	20	1	21	23	-2
	2	10	23	-13	21	21	0	23	23	0	24	22	2
	4	11	24	-13	22	21	1	24	23	1	25	22	3
	6	13	23	-10	22	22	0	25	24	1	26.5	22	4.5
	8	14	23	-9	23	22	1	26	24	2	27	22	5
	10	14	23	-9	24	22	2	26	24	2	28	22	6
	12	15	23.5	-8.5	24	22	2	27	25	2	29	22	7
	14	15	23	-8	24	22	2	28	25	3	29	23	6
	16	15	23	-8	24	22	2	29	25	4	29	23	6
	18	15	23	-8	24	22	2	29	25	4	29	22	7
	20	15.5	23	-7.5	24	22	2	30	25	5			
	22	16	23	-7	25	22	3	30	25	5			
	24	16	23	-7	26	22	4	31	26	5			
	26	16	23.5	-7.5	26	22	4	31	26	5			

team:	time	Table 5:			Table 6:			Table 7:			Table 8:		
	time	T inside	T outside	Table 5	T inside	T outside	Table 6	T inside	T outside	Table 7	T inside	T outside	Table 8
	0	23	22	1	22	21	1	20	23	-3	23	21	2
	2	24	22	2	23	21	2	22	24	-2	24	23	1
	4	26	23	3	25	21	4	24	24	0	25	23	2
	6	27	23	4	26	21	5	25	24	1	26	24	2
	8	28	23	5	27	21	6	26	24	2	27	24	3
	10	29	23	6	28	21	7	26	25	1	28	24	4
	12	30	23	7	28	22	6	27	25	2	28	25	3
	14	31	23	8	28	22	6	28	25	3	29	25	4
	16	31	23	8	29	22	7	28	25	3	29	25	4
	18	31	24	7	29	22	7	28	25	3	30	25	5
	20	32	24	8	29	22	7	28	25	3	30	25	5
	22	32	25	7	29	22	7	29	25	4	30	25	5
	24	33	24	9	29	22	7	29	26	3	30	25	5
	26	33	24	9	29	22	7	30	26	4	30	25	5


"Greenhouse effect" (T inside - T outside)
11
9
7
5
3
1
-1
-3
0
5
10
15
20
25
30
Time (minutes)
Table
Table 1
Table 2
Table 3
Table 4
Table 5
Table 6


Temperature (degrees C)
0
5
10
15
20
25
30
35
time (minutes)
0
5
10
15
20
25
30
Table 1: T inside
Table 1: T outside
Table 2: T inside
Table 2: T outside
Table 3: T inside
Table 3: T outside
Table 4: T inside
Table 4: T outside
Table 5: T inside
Table 5: T outside
Table 6: T inside
Table 6: T outside
Table 7: T inside
Table 7: T outside
Table 8: T inside
Table 8: T outside