SASTA OLIPHANT SCIENCE AWARDS

SOUTH AUSTRALIAN SCIENCE TEACHERS ASSOCIATION

Prize Winner

Scientific Inquiry

Year 5-6

Priyanka Thavarajah

Seymour College

Government of South Australia
Department for Education

SASTA South Australian Science Teachers Association

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Oliphant Science Awards 2020

A Scientific Inquiry

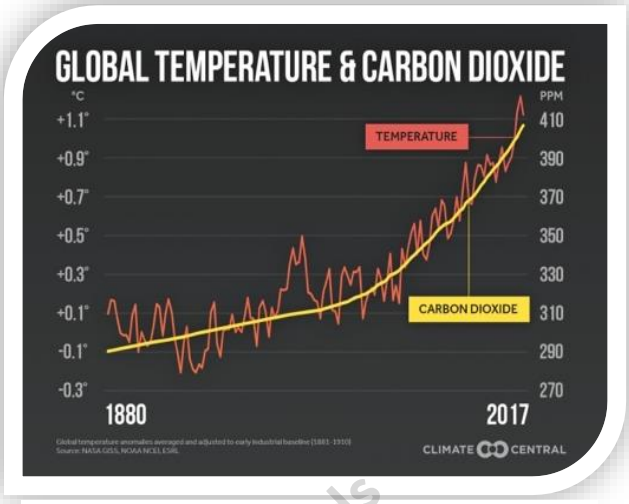
Does increasing the concentration of Carbon Dioxide in the atmosphere cause it to warm?

Priyanka Thavarajah

Class 6.1 Seymour College

Introduction:

This Summer, Australia suffered through a number of heat waves and droughts but, more importantly, these events have resulted in massive and catastrophic bushfires that burnt over 10 million hectares of land. Extreme weather events and natural disasters like this have been thought to be the result of global warming.
The U.S National Academy of Sciences declared "… that humans are changing Earth's climate, primarily through greenhouse gas emissions."



https://www.climatecentral.org/gallery/graphics/co2-and-rising-global-temperatures

These climate scientists believe that a rise in the concentration of greenhouse gases like carbon dioxide in the atmosphere, which is due to human activity such as burning fossil fuels to generate energy, is the key reason for rises in temperature.

A) Questioning and Predicting:

Research Aim:

The aim of this experiment was to prove that rises in Carbon Dioxide will cause rises in atmospheric temperature.

Research Question:

1) Does increasing the concentration of Carbon Dioxide in the atmosphere cause it to warm?

Hypothesis/Prediction:

If there is a greater concentration of Carbon Dioxide in the air, then the temperature of the air in the bottle will be higher. This happens because Carbon Dioxide traps heat that would otherwise escape the bottle.

B) Planning and Conducting:

Planning (Choice of Scientific Method):

Doing a laboratory experiment gives tighter controls on the variables, is replicable and makes it easier to examine the cause and effect.

Variables:

Table 1:

Dependent Variable	The temperature of the air in the bottle
Independent Variable	The mass of ENO (Carbon Dioxide source)
Controlled Variables	The type, size and brand of the bottles
	The type of thermometers
	The distance from the bottles to the heat source (heat lamp)
	The temperature of the room (24^{o}C)
	The volume and temperature of the water
	The weighing scale (electronic)
	The heat lamp
	The volume of air in the bottle

What is a fair test?

A fair test occurs when only one variable (the independent variable) is changed and all other conditions (controlled variables) are kept the same.

To be confident that the test results are true, the independent variable needs to be changed to observe its effect on the dependent variable. A control group (where there is no independent variable) is useful to demonstrate that the independent variable is actually what is making the difference on the dependent variable. In this experiment the independent variable was the varying masses and concentrations of ENO (Carbon Dioxide) and the dependent variable was the temperature of the air in the bottle. A bottle without any ENO was used as the control to show that changes in the temperature was due to the changes in the concentration of ENO.

To be sure about the relationship between cause (independent variable) and effect (dependent variable), all the other variables must be kept constant (controlled variables). All the controlled variables are shown in Table 1.

It's important when setting up a fair test to ensure that any potential biases (systemic and random) are avoided, because they make results inaccurate.

C) Equipment and Materials

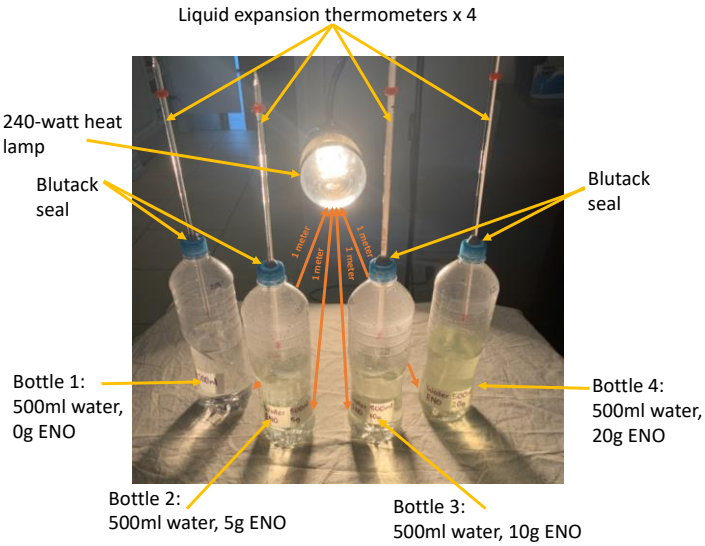
Equipment and Materials:

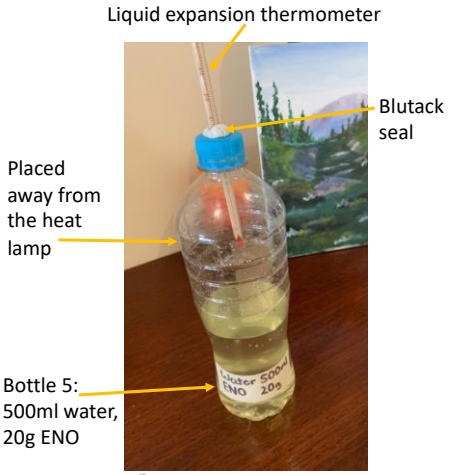
1 litre clear plastic bottle with screw top lid (Mount Franklin) x 5
Label and marker to identify each bottle x 5
2.5 litres of water (room temperature)
55g of ENO (each 5g contains Sodium Bicarbonate – 2.29g, Sodium Carbonate – 0.50g, Citric Acid Anhydrous – 2.16g)
Liquid thermometer x 5
15g of blutack to stop the Carbon Dioxide from escaping the bottles
275-watt heat lamp
Stopwatch
Logbook to record data
Electronic weighing scale (AND HT-3000)
500ml measuring cylinder
Funnel
Screwdriver (to punch a hole into the bottle lids)

Method:

1. Once all the materials had been gathered, holes just big enough for the liquid thermometers to go through were made into all of the 5 bottle lids with the sharp end of a screwdriver.
2. Each thermometer was poked into the newly made hole in the bottle lids (to the $0^{o}C$ mark) so that all the thermometers were equally positioned in the bottles. A sufficient amount of blutack was used to seal any open holes in the bottle lid to stop the carbon dioxide from escaping.
3. Using the measuring cylinder, 500ml of room temperature water was measured and poured into each of the five 1 litre bottles.
4. 5g of ENO was weighed on the electronic weighing scale which was zeroed before the experiment had begun.
5. Using the funnel, the ENO was poured into a bottle already containing 500ml of water.
6. Immediately the bottle lid (with the thermometer already in place) was screwed onto the bottle trapping the carbon dioxide inside.
7. Steps 4 to 6 were repeated with different amounts of ENO (10g, 20g, 20g, 0g) in the remaining bottles.
8. Sticky labels and a marker were used to label each bottle for future identification.
9. 4 of the bottles (0g, 5g, 10g and one of the 20g) were placed in a semi-circle one meter from the heat lamp.
10. The other bottle was placed in a location well away from the heat lamp as another control.
11. The temperature shown on each thermometer was recorded into the logbook for the 0-minute time.
12. The heat lamp was turned on.
13. Every 5 minutes (starting from when the heat lamp was turned on), the temperatures shown on the thermometers were recorded into the logbook.

Annotated Diagrams of the Experiment Setup:





Safety and Risks:

Table 2:

Risks	Steps taken to reduce risks
Heat lamps are very hot and could potentially burn skin.	⇒ Be careful around heat lamps – avoid touching the bulb after turning it on. ⇒ If a burn does occur, run it under cold water. ⇒ Adult supervision is required.
Glass from the thermometer and/or glass heat lamp bulb could shatter and cut skin.	⇒ Be careful when handling the thermometers and the heat lamp bulb. ⇒ If a cut from glass does occur, seek help from an adult. ⇒ Adult supervision is required
Heat lamps run on mains electricity. There is a risk of electrocution.	⇒ Avoid touching the heat lamp with wet hands. ⇒ Observe electrical safety
Chemicals are being used, risk of irritation to skin or eyes	⇒ Wear gloves and safety goggles when handling chemicals ⇒ Wash hands after use

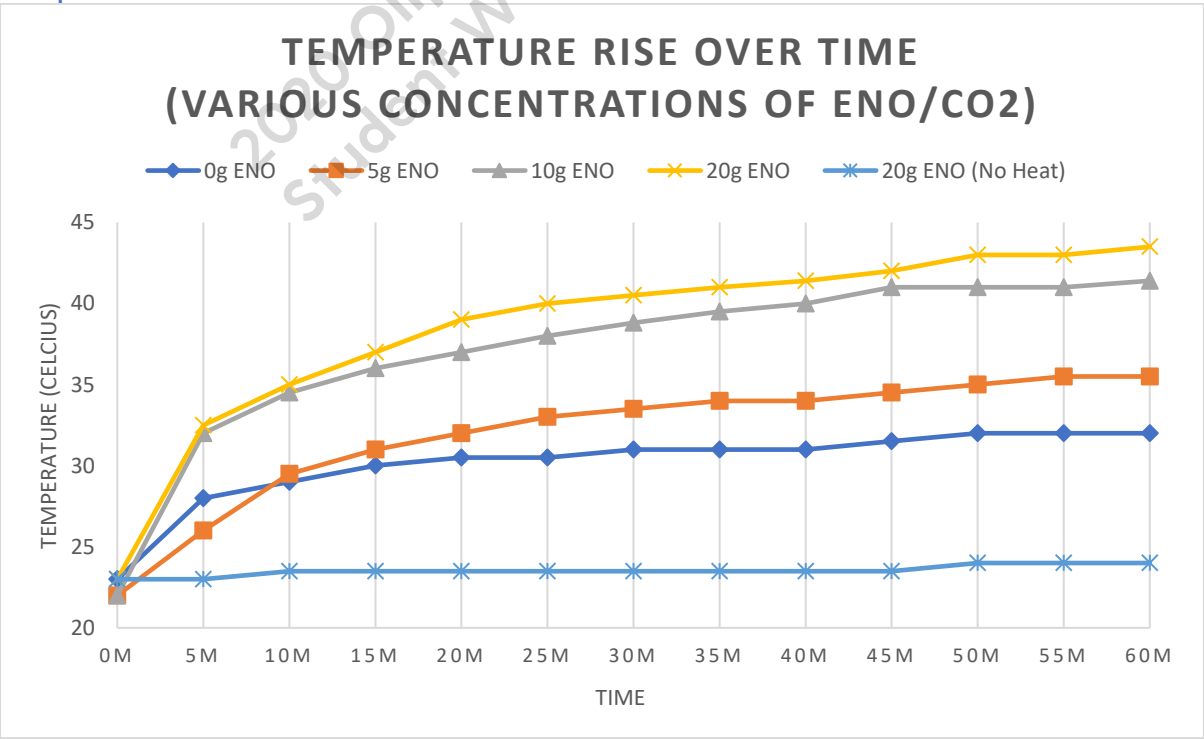
D)Processing and Analysing data and information:

Results:

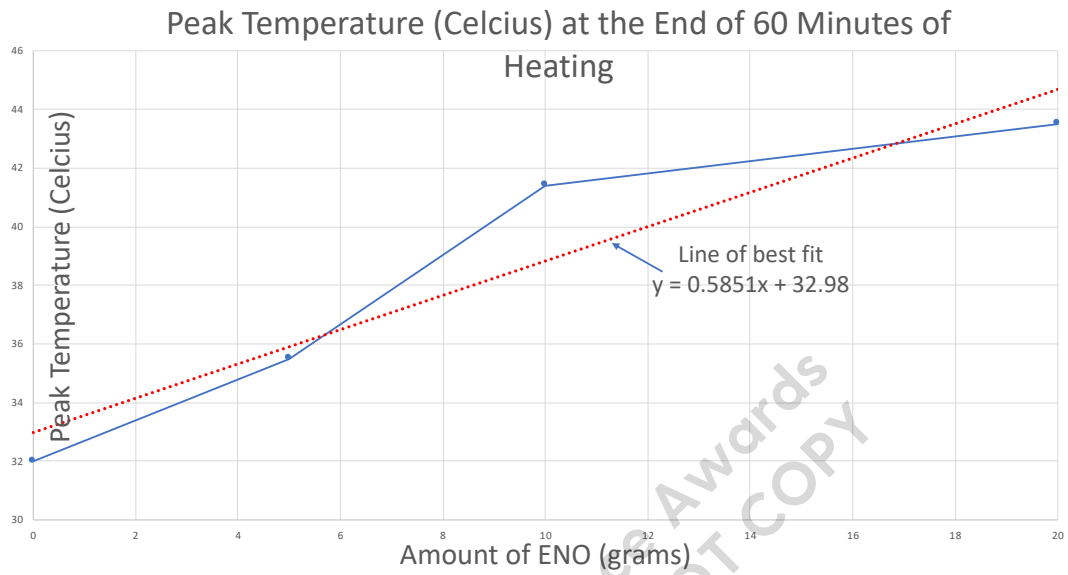
Table 3:

Temperature in Each Bottle Containing Varing Amounts of ENO over 60 minutes					
Time	**0g ENO-ºC**	**5g ENO-ºC**	**10g ENO-ºC**	**20g ENO-ºC**	**20g ENO (No Heat)-ºC**
0m	23	22	22	23	23
5m	28	26	32	32.5	23
10m	29	29.5	34.5	35	23.5
15m	30	31	36	37	23.5
20m	30.5	32	37	39	23.5
25m	30.5	33	38	40	23.5
30m	31	33.5	38.8	40.5	23.5
35m	31	34	39.5	41	23.5
40m	31	34	40	41.4	23.5
45m	31.5	34.5	41	42	23.5
50m	32	35	41	43	24
55m	32	35.5	41	43	24
60m	32	35.5	41.4	43.5	24

Graph 1:



Graph 2:



At 0 minutes, all 5 bottles had a reasonably equal temperature of 22ºC to 23ºC.

By the end of the 60 minutes, the bottle with 20g ENO (no heat) rose by 1ºC. Other than rising by 0.5ºC at the 10-minute and 50-minute mark, the temperature remained constant.

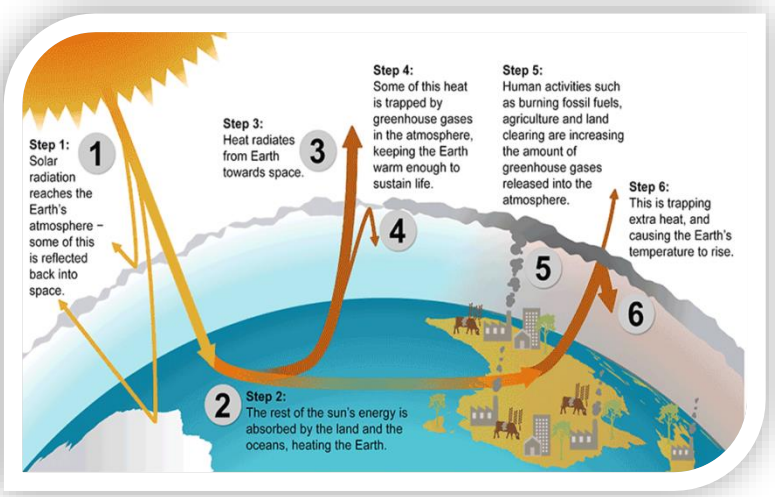
In all the other bottles, the temperature rose rapidly for a certain amount of time before plateauing out. After the first five minutes 0g ENO rose by 5ºC, 5g ENO rose by 4ºC, 10g rose by 10ºC and 20g ENO rose by 9.5ºC.

The first to plateau was the 0g ENO. At the 20-minute mark it had risen by 7.5ºC, after which it started to plateau climbing only 2ºC in the remaining 40 minutes.
The 5g ENO rose by 11.5ºC by the 30-minute mark before plateauing out, climbing 2ºC in the remaining 30 minutes.
The 10g ENO rose by 19ºC by the 45-minute mark before plateauing out, climbing 0.4ºC in 15 minutes.
The 20g ENO rose by 20ºC by the 50-minute mark before plateauing out, climbing 0.5ºC in 10 minutes.

The final temperatures after 60 minutes of heating were: 32ºC for the 0g ENO, 35.5ºC for the 5g ENO, 41.4ºC for the 10g ENO, 43.5ºC for the 20g ENO and 24ºC for the 20g ENO (no heat).

Discussion:

What is the greenhouse effect?
The greenhouse effect is a natural process that keeps the Earth's surface approximately 33°C warmer than it would otherwise be. Without greenhouse gasses (water vapour, Carbon Dioxide, methane etc.), life would not exist on earth.



https://www.environment.gov.au/climate-change/climate-science-data/climate-science/greenhouse-effect

The Sun's radiation (electromagnetic energy) in the form of heat, light and some ultraviolet waves penetrate the earth's atmosphere and reaches the surface where it is absorbed and heats up the earth. The energy is then emitted back towards space as infrared waves. Even though some of these infrared waves escape, the greenhouse gases in the atmosphere absorbs and reflects some back to earth, trapping the heat in the atmosphere. This process is called the greenhouse effect.

However, in the last 150 years, human activities have caused rapid rises in the amount of carbon dioxide in the air, primarily because of burning fossil fuels such as coal, petroleum and natural gases. This sudden increase of the concentration of Carbon Dioxide in the atmosphere is thought to be the cause of the gradual heating of the Earth's surface, oceans and atmosphere, also known as global warming (**enhanced greenhouse effect**).

The experiment was carried to test this hypothesis and show the relationship between increases in concentration of Carbon Dioxide and increases in temperature.

ENO is an antacid. Each 5g contains 2.29g of Sodium Bicarbonate, 0.50g of Sodium Carbonate and 2.16g of Citric Acid Anhydrous. In the tightly sealed package, the Citric Acid is inert since it is dry (anhydrous). But, when dissolved with water, it dissociates and performs a series of reactions.

The Sodium Bicarbonate and Citric Acid react forming Sodium ions and Citrate ions (which react with each other again, forming salt), some water and an ample of Carbon Dioxide.

$NaHCO_3 + H^+ \rightarrow Na^+ + H_2O + CO_2$

Similarly, the Sodium Carbonate and Citric Acid react forming Sodium ions and Citrate ions (which react with each other again, forming salt), some water and even more Carbon Dioxide.

$Na_2CO_3 + 2H^+ \rightarrow 2Na^+ + CO_2 + H_2O$

In the experiment, different amounts of ENO were used (0g, 5g, 10g and 20g) since they would produce different amounts of Carbon Dioxide. More ENO meant more Carbon Dioxide being produced.

In the result section, it can be seen that the temperature in each of the bottles holding various concentrations of ENO seemed to rise rapidly then plateau out. The higher concentration of ENO, the higher the temperature rose before it started to plateau.

Since each bottle was placed 1 meter away from the heat lamp, a fixed amount of energy was provided to each bottle. While the molecules in the bottles were receiving energy, just like in the atmosphere, they also would be radiating some back out, depending on the temperature. Since the bottle is much colder than the heat lamp at the beginning, the temperature in the bottle rises rapidly. But as the bottle gets hotter, it radiates more energy out and eventually the amount of energy received and radiated is equal and the temperature stops rising. This is where the temperature plateaus.

Obviously, the higher concentration of Carbon Dioxide, the more heat it will be able to trap in, therefore making the point where the energy received and radiated is equal, higher. This is why the temperature of the bottles with higher concentrations of Carbon Dioxide plateau at a higher point.

This result confirms the hypothesis that a greater concentration of Carbon Dioxide in the air will lead to higher temperatures.

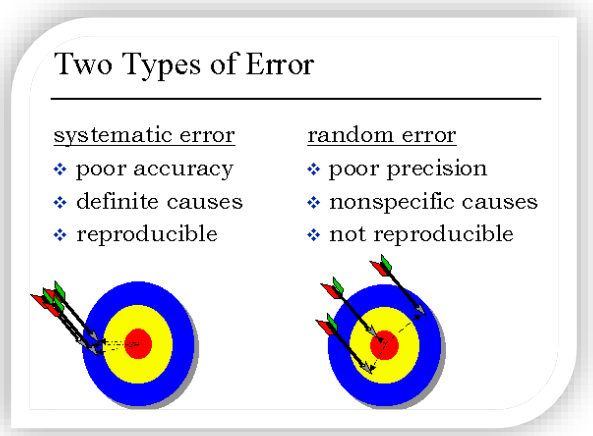
To ensure that the raised temperature observed was due to heat trapped by the Carbon Dioxide rather than produced by the chemical reaction of the ENO in the water, a control bottle with 20g of ENO (maximum amount of ENO) and 500ml of water was placed well away from the heat of the heat lamp. At the end of the 60 minutes, the temperature inside the bottle had risen by only 1^{o}C, while the identical bottle (20g ENO, 500ml water), 1 meter away from the heat lamp, rose by 20.5^{o}C.
The small rise of 1^{o}C inside the control bottle was most likely caused by equilibration with the room temperature (24^{o}C). Therefore, the ENO does not produce its own heat and the experiment is a fair test.

E) Evaluation:

Potential Errors:

There are many kinds of errors that could have occurred during the length of this experiment, the main 2 being systematic and random errors.

Systematic errors occur when the same error repeats again and again. 2 types of systematic errors that may have occurred in the experiment are parallax and zeroing errors.



https://www.facts-about-india.com/errors-in-measurement.php

When reading the temperatures on the liquid expansion thermometers, a slight change of angle (not reading the markings from eye level) could have made a big difference in the results leading to an unfair and inaccurate experiment. This parallax error could have been fixed by using electronic thermometers which, however, are unfortunately quite expensive, especially if 5 were needed.

A zeroing error might have occurred when using the thermometers and they might have read the wrong numbers. This problem could have been solved by calibrating the thermometers before the experiment begun.

Random errors are hard to prevent, as they can happen anywhere at any time. For example, the different lengths of time taken to screw on the lids of the bottles after the ENO had been added could have severely affected the results, since different amounts of the Carbon Dioxide would have escaped, and the amount left would have been underestimated.

Another random error could have occurred when measuring the ENO on the electronic weighing scale. Since the electronic weighing scale used rounded the weight of the ENO to the nearest gram, what was thought to be 5g could have actually been 5.4g or 4.5g. This imprecision could have led to inaccurate results and an incorrect conclusion would have been drawn.

Repeating this experiment 3 times then averaging the result would have minimised the effects of random errors.

Improvements:

Other than fixing these errors, another improvement for this experiment would have been to use pure Carbon Dioxide. Although it may have been harder to find, using pure Carbon Dioxide would have given more accurate results, since the for every 5g ENO used in this experiment there was 2.29g of Sodium Bicarbonate, 0.50g of Sodium Carbonate and 2.16g of Citric Acid Anhydrous. As mentioned before, after a series of reactions, Citric Salts, some water and an ample of Carbon Dioxide was formed. This raises the question, what if the Citric Salts are trapping the heat not the Carbon Dioxide? To overcome this problem, pure Carbon Dioxide should have been used, making it clear that the Carbon Dioxide itself was trapping the heat.

Further Investigations:

Further investigation, in relation to this topic, would have included using much larger amounts of ENO (50g, 100g, 150g, 200g) in addition to the smaller ones (0g, 5g, 10g, 20g). This would have tested if the rise in Carbon Dioxide continues to create rises in temperatures in a linear fashion or plateaus out. Maybe the temperature starts to drop after a certain amount of ENO is added. By extending the range of amounts of ENO used, new information will be gathered, helping make more accurate inferences and connections to the real world.

Usefulness of investigation:

These findings add to the body of scientific conclusions that scientists have been working on for years. Since the hypothesis, rises in Carbon Dioxide causes rises in temperatures, has been proven to be true, it can be inferred that global warming is due to the rises in Carbon Dioxide in the atmosphere. With this fact in mind, hopefully the vast population of human beings who create so much Carbon Dioxide a day, will take a step back and reduce their Carbon footprint, helping to save Mother Earth.

Conclusion:

The results of this experiment show a positive linear relationship between the concentration of the Carbon Dioxide and the rise in temperature proving the hypothesis to be true. Therefore, if humans continue to release large amounts of Carbon Dioxide into the atmosphere, Global Warming will be inevitable and the severe bushfires, heat waves and droughts that Australia went through last Summer will continue to happen.

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Acknowledgements:

My Dad helped me understand the chemical and physical theory behind my experiment and supervised me during the most dangerous parts.

- Logbook is enclosed as a separate document
- Risk assessment for Scientific Inquiry enclosed as a separate document