Qualitative Data

There wasn't any qualitative data collected in this lab that helped further one's understanding of how different colors of light affect photosynthesis as measured by the percentage of oxygen gas (± 0.01%) in the air.

Quantitative Data

Result Table

The Effect of the Different Colors of Light on Photosynthesis Measured As By the Percentage of Oxygen Gas (± 0.01%) in the Air Over a 600 Seconds (± 0.005 Seconds) Period of Time

The Percentage of Oxygen Produced (±0.01%)	**Time (±0.05 Seconds)**									
	60	*120*	*180*	*240*	*300*	*360*	*420*	*480*	*540*	*600*
Blue Light (475nm)	16.50	16.62	16.55	16.59	16.62	16.66	16.69	16.72	16.75	16.77
Red Light (680nm)	16.61	16.63	16.65	16.68	16.71	16.73	16.75	16.77	16.79	16.80
Green Light (540nm)	16.50	16.50	16.50	16.51	16.51	16.51	16.52	16.52	16.52	16.53
White Light	16.52	16.53	16.54	16.57	16.59	16.63	16.64	16.67	16.69	16.71

Uncertainties Explained:

- Time (±0.05 Seconds): The uncertainty for time would be ±0.05 seconds because it is how the stopwatch measures the amount of time, the amount of nanoseconds is rounded to ±0.05 seconds.
- The Percentage of Oxygen Produced (±0.01%): the logger which calculates the percentage of oxygen only rounds to two decimal places therefore the uncertainty is ±0.01%.

Raw Data:

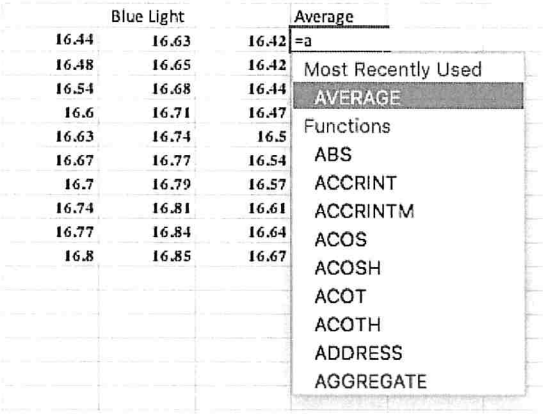
Blue Light				Rounded	STDEV
16.44	16.63	16.42	16.4966667	16.5	0.09
16.48	16.65	16.42	16.5166667	16.52	0.1
16.54	16.68	16.44	16.5533333	16.55	0.1
16.6	16.71	16.47	16.5933333	16.59	0.1
16.63	16.74	16.5	16.6233333	16.62	0.1
16.67	16.77	16.54	16.66	16.66	0.09
16.7	16.79	16.57	16.6866667	16.69	0.09
16.74	16.81	16.61	16.72	16.72	0.08
16.77	16.84	16.64	16.75	16.75	0.08
16.8	16.85	16.67	16.7733333	16.77	0.08

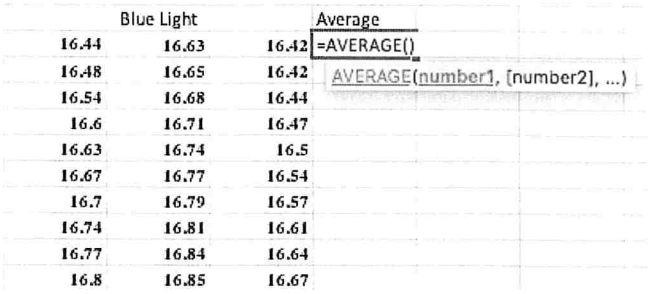
Red Light				Rounded	STDEV
16.53	16.69	16.6	16.6066667	16.61	0.07
16.53	16.72	16.63	16.6266667	16.63	0.08
16.55	16.74	16.66	16.65	16.65	0.08
16.58	16.76	16.7	16.68	16.68	0.07
16.61	16.78	16.73	16.7066667	16.71	0.07
16.63	16.8	16.76	16.73	16.73	0.07
16.66	16.81	16.78	16.75	16.75	0.06
16.69	16.82	16.8	16.77	16.77	0.06
16.72	16.83	16.82	16.79	16.79	0.05
16.74	16.83	16.82	16.7966667	16.8	0.04

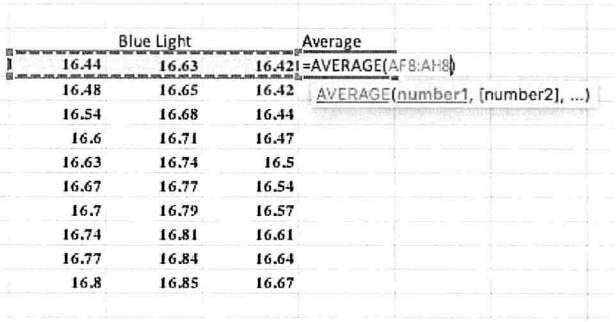
Green Light				Rouned	STDEV
16.54	16.48	16.48	16.5	16.5	0.03
16.54	16.48	16.48	16.5	16.5	0.03
16.54	16.48	16.49	16.5033333	16.5	0.03
16.54	16.5	16.49	16.51	16.51	0.02
16.54	16.5	16.49	16.51	16.51	0.02
16.55	16.5	16.49	16.5133333	16.51	0.03
16.55	16.51	16.5	16.52	16.52	0.02
16.56	16.51	16.5	16.5233333	16.52	0.03
16.56	16.51	16.5	16.5233333	16.52	0.03
16.56	16.52	16.5	16.5266667	16.53	0.02

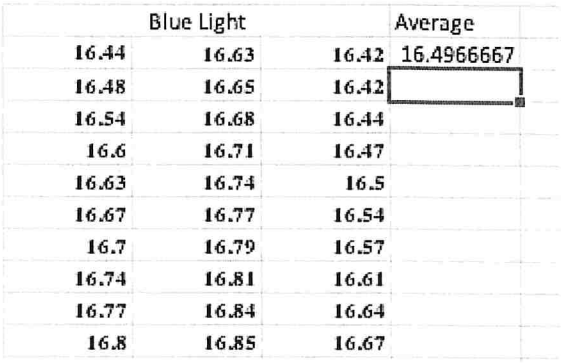
White Light				Rounded	STDEV
16.5	16.53	16.53	16.52	16.52	0.01
16.51	16.54	16.53	16.5266667	16.53	0.01
16.53	16.55	16.55	16.5433333	16.54	0.01
16.56	16.58	16.57	16.57	16.57	0.01
16.59	16.6	16.59	16.5933333	16.59	0
16.63	16.63	16.62	16.6266667	16.63	0
16.65	16.64	16.64	16.6433333	16.64	0
16.68	16.66	16.66	16.6666667	16.67	0.01
16.7	16.68	16.69	16.69	16.69	0.01
16.73	16.7	16.7	16.71	16.71	0.01

Calculating the Average
On Excel:









Or

$$\frac{(16.44+16.63+16.42)}{3} = Average = 16.4966667 \rightarrow \frac{(Trial\ 1 + Trial\ 2 + Trial\ 3)}{Number\ of\ Trials} = Average$$

Rounding

Blue Light			Average	Rounded (to Two Decimal Places)
16.44	16.63	16.42	16.4966667	16.5
16.48	16.65	16.42		
16.54	16.68	16.44		
16.6	16.71	16.47		
16.63	16.74	16.5		
16.67	16.77	16.54		
16.7	16.79	16.57		
16.74	16.81	16.61		
16.77	16.84	16.64		
16.8	16.85	16.67		

The Logger calculates percentage of oxygen gas to two decimal places, therefore since all the values need to be to the same amount of digits, everything is rounded to two decimal places.

Standard Deviation

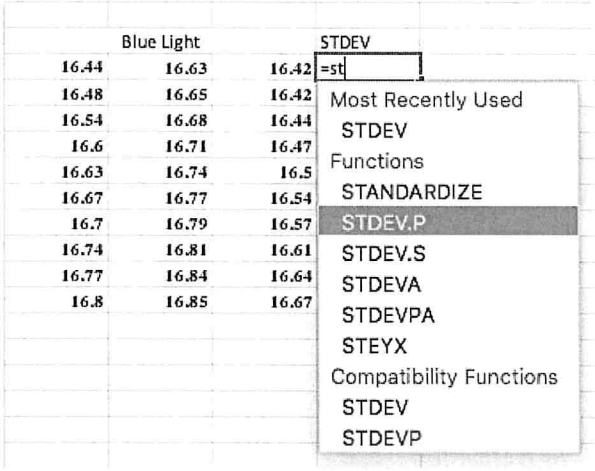
The Equation:

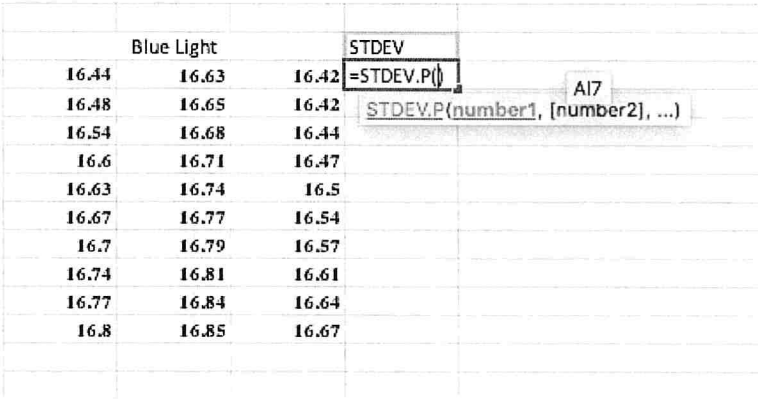
$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2}$$

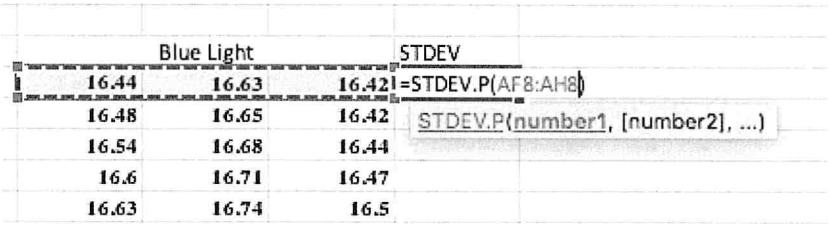
Math Is Fun. "Standard Deviation Formulas." *Math Is Fun*, www.mathsisfun.com/data/standard-deviation-formulas.html. Accessed 30 Oct. 2018.

Or

On Excel:

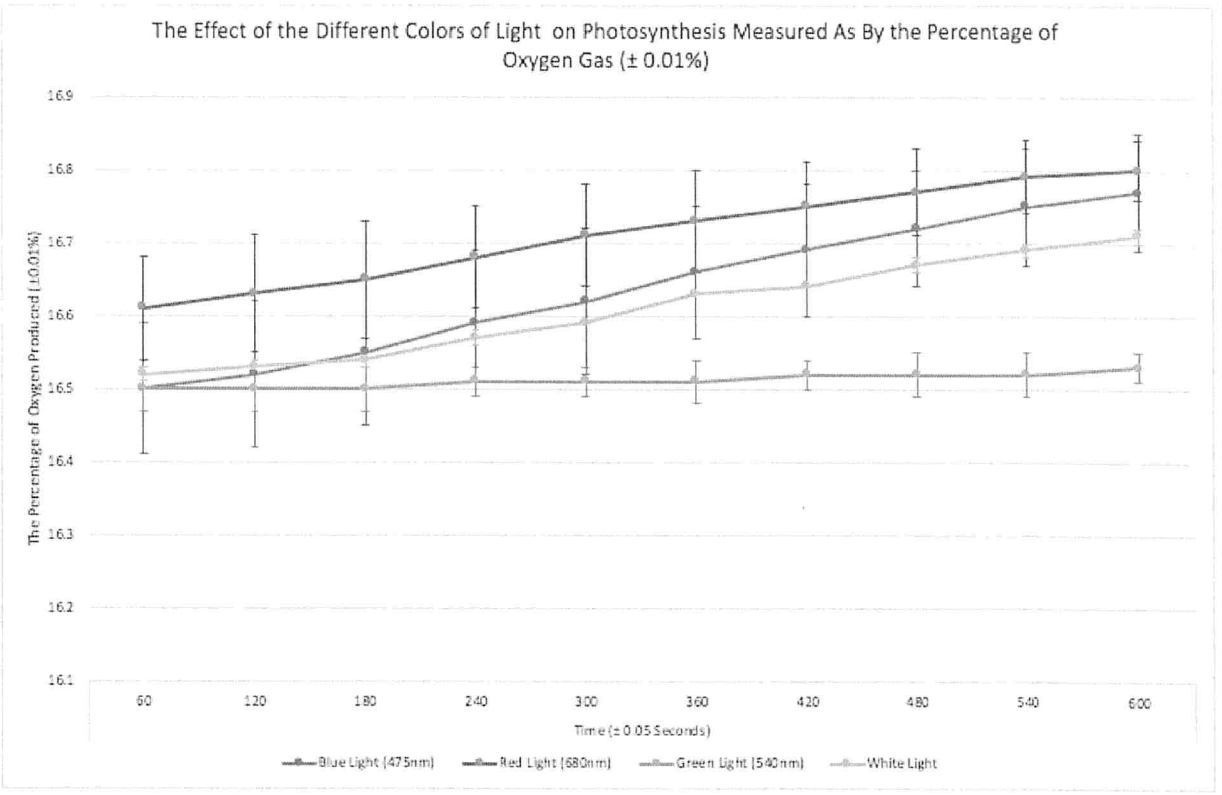






Blue Light			STDEV
16.44	16.63	16.42	0.0946338
16.48	16.65	16.42	
16.54	16.68	16.44	
16.6	16.71	16.47	
16.63	16.74	16.5	
16.67	16.77	16.54	
16.7	16.79	16.57	
16.74	16.81	16.61	
16.77	16.84	16.64	
16.8	16.85	16.67	

Graph

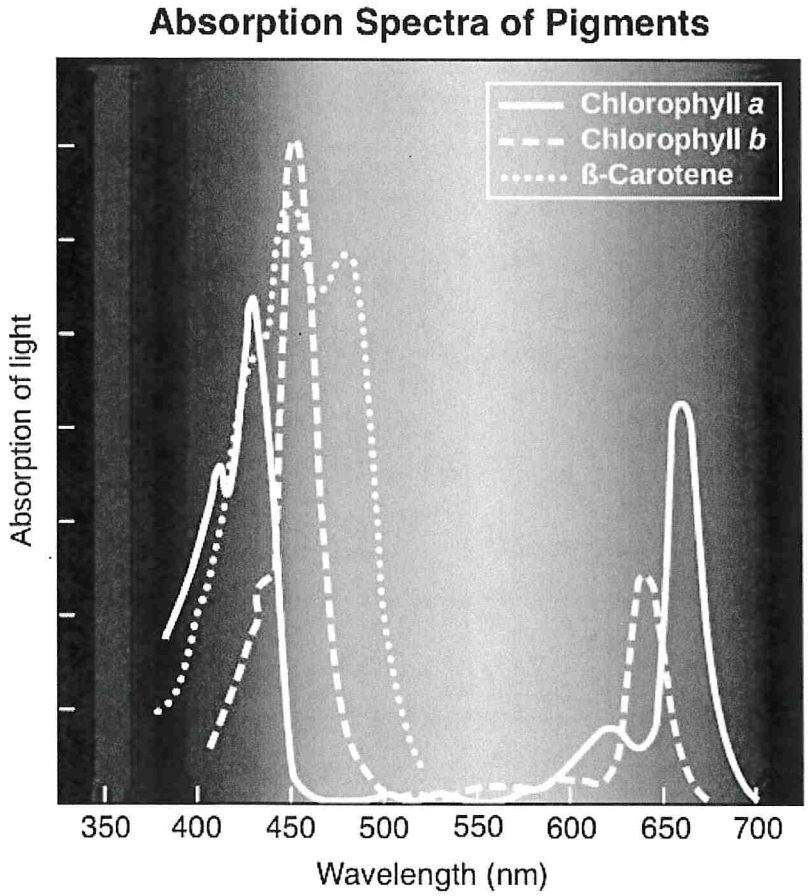


Error Bars represent the standard deviation.

Conclusion

My hypothesis was that the percentage of oxygen gas (±0.01%) would produce/increase more rapidly during the usage of the blue and red filter. As demonstrated above in my graph and table, the red light and blue light increased the quickest out of the four colors. Both trend lines show a rapid increase throughout the process of photosynthesis though the blue light had fastest increase in the percentage of oxygen gas produced (±0.01%) and was quicker red light. It is difficult to see in the graph since both light colors began with different amounts of oxygen but looking at the table, blue light began with 16.50% (±0.01%) as its percentage of oxygen gas produced in 60 seconds and ended with 16.77% (±0.01%) as its percentage of oxygen gas produced in 600 seconds. The difference between the two percentages is 0.27% (±0.01%) whereas the red light began with 16.61 (±0.01%) as its percentage of oxygen gas produced in 60 seconds and ended with 16.80% (±0.01%) as its percentage of oxygen gas produced in 600 seconds. The difference between the two percentages for red light is 0.19% (±0.01%). This demonstrates that the blue light had the greatest increase in the percentage of oxygen gas produced. Though both red and blue wavelengths are both very effective in photosynthesis since the colors are the correct amount of energy to energize the chlorophyll electrons (Dickson and Byju), blue light shows a larger increase of percentage of oxygen gas produced (Excite). Red light has both the photosystems (PS I PS II) which absorb the wavelengths in the red region (680-700 nm) whereas blue light is absorbed by carotenoids (Byju), another group of pigments that take in the excess energy and dissolves it as heat (Khan Academy). Blue light is better absorbed by chlorophyll a (which is in *Geranium L.*) than

red light (Khan Academy). Chlorophyll a has a main role in photosynthesis because it converts light energy into chemical energy and since it absorbs blue light better, the increase in the percentage of oxygen produced will be greater than red light.



Khan Academy. "Light and photosynthetic pigments." *Khan Academy*, www.khanacademy.org/science/biology/photosynthesis-in-plants/the-light-dependent-reactions-of-photosynthesis/a/light-and-photosynthetic-pigments. Accessed 30 Oct. 2018.

As shown in the graph above, chlorophyll a absorbs the blue colors more effectively than the reds..

My hypothesis also stated that there will be a steady rate of the percentage of oxygen gas produced (±0.01%) for white light (normal light). In the graph and the data table, it says otherwise. There is a rapid increase in the percentage of oxygen gas produced throughout the experiment shown in the trendline. The white light began with 16.52% (±0.01%) as its percentage of oxygen gas produced in 60 seconds and ended with 16.71% (±0.01%) as its percentage of oxygen gas produced in 600 seconds. The difference between the two percentages is 0.19% (±0.01%) which is the same difference between the beginning and ending percentages of the red light. ~~According to the research~~, the normal light would cause a steady rate of the percentage of oxygen gas produced because white light contains a mixture of all the colors therefore it should have a steady trendline.

As stated in my hypothesis earlier, the percentage of oxygen gas produced (±0.01%) for the green filter did not increase rapidly like the other colors. As shown in the graph and the data table, there is barely an increase in the percentage of oxygen gas produced for the green fitler in the trendline. The green light began with 16.50% (±0.01%) as its percentage of oxygen gas produced in 60 seconds and ended with 16.53% (±0.01%) as its percentage of oxygen gas produced in 600 seconds. That is a difference of 0.03% (±0.01%). The increase of the percentage of oxygen gas is very little because none of the pigments absorb green light, instead it reflects the light which why the plants look green (Byju).

In conclusion, blue light had the fastest increase in percentage of oxygen gas produced unlike green light which barely increased. Understanding the rate of photosynthesis allows one to learn more about our ecosystem and how photosynthesis is a big part of life. Learning that colors help increase the rate of photosynthesis helps improve the future because that knowledge can be applied to create new technological advances and improve plant growth.

Evaluation

Evaluation of experimental limitations or strengths		
Source of Errors	To what extent did it affect the results	Improvements
<u>Independent variable</u> The Different Colors of Light (Blue Light, Red Light, Green Light and White Light)	The colors blue, red, green and white are an appropriate range chosen for this experiment since it allows one to explore the main parts of the visible light spectrum (wavelength of light) since the colors are from different sections of the spectrum. One can now see the affect different colors of light on photosynthesis with this range. The independent variable was manipulated effectively, efficiently and easily during the experiment. One only had to tape the filter onto the light and turn on the light for that color light to shine, then once one is finished with the trials, they only have to remove the filter and tape on a new one. A possible effect on data was that during the first couple trials with a green filter, the filter was not entirely attached to the lamp meaning that not only green light but white light as well struck the *Geranium L.* which affects the photosynthesis and the percentage of oxygen gas produced.	A suggested improvement for the independent variable would be to make sure that the filter is secured to the lamp before beginning each trial to ensure that white light will not strike upon the plant (unless that trial is white light or regular light), other than that colored filters to control the independent variable was a strength because it was very simple and easy to manipulate to produce positive results with the experiment.

<u>Dependent variable</u> The Percentage of Oxygen Gas Produced (±0.01%)	The method of measurement was to use the oxygen gas sensor which is connected to the LabQuest and a laptop in order to use the Logger Pro which measures the percentage of oxygen gas (±0.01%). The oxygen gas sensor is then attached to a corner inside the plastic box, not touching the bottom of the box because if the sensor touches the ground, it will not be recording the oxygen gas effectively. One would tape Clingfilm into the top to prevent air from escaping during the experiment and once it's completed, one would remove the Clingfilm to allow the air to escape and reset for ten minutes. This method of measurement was effective if one remembers to reset the experiment and allows the air to escape the box. All of the trial values were close to the average which demonstrates the accuracy of the values. There was a possible effect on the data since the sides of the container were stuck down meaning that no air would enter or exit the plastic box which would add to the reliability of the results being accurate, so the experiment did not reset completely. The amount of air allowed to enter the box during the experiment and the amount released after the trial, would have an effect on the data because the amount of CO2 affects photosynthesis. One did not include the original amount of oxygen in the box before beginning the trial therefore the data is incorrect.The amount of equipment used was sufficient but it was very wasteful and harmful to the environment since one has to use new tape and Clingfilm for each trial.	This method for this experiment was very complicated and harmful to the environment. The Clingfilm was not the most reliable material to cover the top of a plastic box, even if tape stuck the top down. Clingfilm is more reliable when stuck to glass therefore a suggested improvement would be to change the plastic box to a glass box instead, this also solves the problem of using a lot of tape and Clingfilm because then the Clingfilm will stick easier to the glass and one would not have to change the Clingfilm each trial/whenever the Clingfilm falls off often. The method of measurement was a strength because using the Logger Pro is known for its reliable data (Vernier). Also another improvement would be to record the amount of oxygen inside the box before the trial to receive more accurate data.

Control Variables	To what extent did it affect the results	Improvements
Species of Plant (*Geranium L.)*	If the same type of plant is not used not every trial, it will have an effect on	A limitation of this control variable would be that the

	photosynthesis and the percentage of oxygen gas produced (±0.01%). The same exact plant, *Geranium L.* was used throughout the whole experiment and every trial therefore it was controlled effectively.	plant was exhausted and ten minutes to allow the air to escape and circulate/the plant to rest, the plant might not have fully recovered therefore it affected the data. In the experiment, one did use the same species of plant but that did not mean one had to use the exact same plant throughout the whole experiment. An improvement could be to use at least four different plants of the same species (*Geranium L.*) to ensure the most reliable data, one for each color of light.
Size of Plant (*Geranium L.)*	If the plant *Geranium L.* is not the same size/similar size than it will affect the rate of photosynthesis and the data will not be reliable. The larger the plant, the more light it can absorb because the larger the surface of the leaf (Sarlikioti), the more light the plant can take in. In this experiment, the same, exact plant was used throughout the whole process therefore the size of the plant did not affect the data. The size of the plant was effectively controlled.	The size of the plant did not affect the data and was controlled well because it was the same, exact plant used but using the same, exact plant could affect the data since the plant has already photosynthesized a lot (see above for more explanation).
Type of Lamp	If different lamps are used throughout the experiment, it affects the data since every lamp provides a different light intensity which affects photosynthesis therefore one must use the same lamp. In this experiment, one used a 12-V 36-W line-filament lamp throughout the whole process. An effect on the data would be that the heat of lamp also affects the photosynthesis and the percentage of oxygen gas produced which is what one is measuring as its independent variable. Temperature of the light source is a limiting factor of photosynthesis	This control variable was not controlled very well since the type of lamp produces heat (has a high temperature) that affects photosynthesis or in this case, the amount of oxygen gas produced. A suggested improvement would be to use an LED lamp since it does not produce heat (Alexander) which will allow the data to become more reliable.

	(Markings) and therefore affects the reliability of the data.	
Position of the Oxygen Gas Sensor	Different positions of the oxygen gas sensor would affect data since the sensor might create different oxygen readings. The oxygen sensor was attached to the same corner of the plastic box for each trial and did not move. It was controlled effectively.	This control variable was a strength because the oxygen gas sensor did not move at all during the experiment, it stayed in the exact, same corner. This was a very simple variable to control.
Position of the Plant	If the plant is not in the same position every time, other trials might have an advantage because the plant might be closer to the light or hidden from the light. A possible effect on the data was that the *Geranium L.* plant might have moved throughout the experiment either closer to the light or away from it. This makes the data not as reliable since not all the trails are fair or accurate.	This was a limitation to the experiment and a suggested improvement would be to tape the plant if in a container or a pot to the bottom of the box or to mark where the plant is like drawing a circle around it and making sure that before and after each trial, the plant is in the correct spot.
Position of the Lamp	If the lamp is not in the correct position, the light might not strike the plant. Also if the lamp moves every trial, either closer to the plant or further away, it will also affect the accuracy of the data. A possible effect on the data was that the lamp might not have been in the exact same place throughout the whole experiment or striking the plant fully.	This was a limitation to the experiment and a suggested improvement would be to tape down and mark where the lamp should stay at all times in order to receive the most accurate data.
Environment of the Experiment	This must be controlled to make sure that other factors that affect photosynthesis such as light will affect the percentage of oxygen produced gas from the *Geranium L.* to ensure effective trials. During the experiment, all the lights were turn off in the room and the lamp was the only light source. One did not take into account the temperature of the room and how that affects photosynthesis.	This was a limitation to the experiment and a suggested improvement would be to keep the room at the same temperature (room temperature) so that it is not too hot or cold to affect photosynthesis. Also to ensure that no light besides the lamp would enter the plastic box is to tape cardboard to the sides of the box to prevent all light except

		the lamp to enter the box.

Uncontrolled variables	To what extent did it affect the results	Improvements
Condition of the Plant Prior to the Experiment	If one has the choice between a healthy plant or a yellow unhealthy plant, one should choose the healthy one since it will produce the best data results during the experiment. The healthy plant will produce more oxygen gas than the unhealthy one meaning that there is more data to collect. During the experiment, a healthy *Geranium L.* was used to produce the best results.	This was a strength since using a healthy plant has positive results and helps create more data to analyze.
The Amount of Chlorophyll	Chlorophyll affects the rate of photosynthesis since it channels the energy of light into a synthetic energy, it also converts water and carbon dioxide to oxygen and carbohydrates (Rose). The more chlorophyll, the faster the rate of photosynthesis. No one can control the amount of chlorophyll in the plant. During the experiment, one chose the healthiest *Geranium L.*	This was a strength since using a healthy plant improved the percentage of oxygen produced and the data was better.

Next steps

A next step to improve this experiment would be to look beyond visible light, but to everything on the electromagnetic spectrum such as how x rays, microwaves, ultraviolet light, infrared light, and more to see how it affects photosynthesis. It would be interesting to figure out and research how to conduct experiments with the electromagnetic spectrum and all the different types of radiation and how it affects plants growth because maybe in the future, that is the way photosynthesis will happen.

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