EXPERIMENTAL DESIGN REFERENCE

Scenario: **A group of students is assigned a Populations Project in their Ninth Grade Earth Science class. They decide to determine the effect of sunlight on radish plants. They grow 12 radish plants in 4" clay pots with 25 mL of water daily and 100 g of potting soil in 24 hours darkness, 12 hours sunlight/12 hours darkness, and 24 hours sunlight. (They use Grow-Lights to simulate sunlight.) After 5 days, they measure the height of all the plants in each pot.**

1. TITLE: Communicates what your experiment is about.

The Effect of (the independent variable) **on** (the dependent variable.)

Example: **The Effect of** Sunlight **on** the Height of Plants.

2. HYPOTHESIS: Communicates what you think is going to happen in the experiment.

If (the independent variable) **is** (increased, decreased, changed)**,**
then (the dependent variable) **will** (increase, decrease, change.)

Example: **If** the sunlight **is** increased, **then** the height of the plants **will** increase.

3. **INDEPENDENT VARIABLE:** (I.V.) Also called the **Manipulated Variable**. The variable you purposely change or manipulate. Will be the CAUSE of the changes you measure.

Example: The Sunlight

LEVELS: The values you choose for your Independent Variable.

Example: 24 hours of darkness, 12 hours of sunlight / 12 hours of darkness, and 24 hours of sunlight.

TRIALS: The number of times each level is repeated. Could be the number of seeds in a pot, or the number of fish in a fish bowl.

Example: 12 radish seeds in each pot = **12 trials** for each level of sunlight

4. **DEPENDENT VARIABLE:** The variable that responds. Also called the **Responding Variable**. The variable you will measure after the experiment is set up. Will be the EFFECT of the action you took.

Example: The Height of the Plants.

5. **CONSTANTS:** All the other variables that **remain the same** for all the trials. Must be quantified. (Include numbers.)

Example: 4" pots, 100 g potting soil, 25 mL water daily

6. **CONTROL:** A level that does NOT contain the independent variable. The NO TREATMENT GROUP or NORMAL TREATMENT GROUP. Gives you a way to detect hidden variables.

Example: the level in the above scenario that most acts like **NORMAL** for plants would be the 12 hours sun / 12 hours dark. You are comparing the 24 hours darkness and 24 hours sunlight to the normal situation for plants.

EXPERIMENTAL DESIGN FORMAT:

This format is <u>required</u> for every experiment! **<u>NOTE: THIS IS NOT THE DATA TABLE!!</u>**

Title: The Effect of Sunlight on the Height of Plants.

Hypothesis: If the sunlight is increased, then the height of the plants will increase.

I.V. Amount of sunlight (hours)

Levels:	**0**	**12**	**24**
Trials:	12	12	12

D.V. The Height of plants (cm)

Constants: (1) 4" pots (2) 25 ml water daily (3) 100 g soil

Controls: 12 hours sunlight / 12 hours darkness

CHECKLIST FOR EVALUATING YOUR EXPERIMENTAL DESIGN:

1. TITLE: Does the title clearly identify both the independent and dependent variable? Have you used the words THE EFFECT OF and ON?			
2. HYPOTHESIS: Does the hypothesis clearly state how you think changing the I.V. will affect the D.V.? Have you used the words IF, IS INCREASED OR DECREASED, THEN, and WILL INCREASE OR DECREASE?			
3. INDEPENDENT VARIABLE: Is there an independent variable that is clearly the CAUSE?			
4. LEVELS: Are the levels of the I.V. clearly stated? Are there enough levels for a valid experiment?			
5. TRIALS: Are there enough repeated trials to make it a valid experiment?			
6. DEPENDENT VARIABLE: Is there a dependent variable that is clearly the EFFECT?			
7. OPERATIONAL DEFINITION: Are the independent and dependent variables operationally defined? Remember: this means the unit of measure is given. (hours) (cm)			
8. CONSTANTS: Are the constants clearly identified and described? Are there any others that should be mentioned? Are numbers used?			
9. CONTROL: Is a control mentioned if possible? If not, is N / A used instead?			
10. EXPERIMENTAL DESIGN FORMAT: Does the experimental design follow the required format? Include all the parts? Are the parts placed in the proper order?			
11. CREATIVITY: Is the experiment creative? Is it at a high school level of complexity?			

PROCEDURE: Write a detailed and precise **procedure** that includes both the correct sequence of steps to be taken and the materials / equipment needed. The procedure should be detailed enough so that another experimenter could duplicate the experiment without having to ask you ANY questions! Write for one level of the independent variable and add repetitions for repeated trials. Most steps should include a **number** of some kind: size of pot in mL, amount of soil in grams.

A **flowchart** could also be used as a procedure. A flowchart is a combination of pictures and brief descriptive words to explain the pictures.

CHECKLIST FOR EVALUATING YOUR <u>PROCEDURE</u>:

1. All important steps included.				
2. All materials and equipment included.				
3. Procedure is written for one level of the independent variable.				
4. You have included repetitions for repeated trials.				
5. You have included repetitions for levels of the independent variable.				
6. You have written in an approved format: list, paragraph, or flowchart.				
7. You have included all important numbers / brand names of materials and equipment required for the experiment.				
8. Spelling and grammar are correct.				
9. Sentence and / or paragraph structure is correct.				

DATA TABLE: Although there are no universal rules for constructing data tables, generally accepted guidelines and conventions do exist. For example, the independent variable is almost always recorded in the left column and the dependent variable in the right. When repeated trials are conducted, they are recorded in subdivisions of the dependent variable column. If derived quantities, such as the average height are calculated, there are recorded in an additional column to the right.

When recording data in a table, the values of the I.V. are ordered from smallest to largest. The title of the data table should communicate the purpose of the experiment and mention both the I.V. & D.V. Example:

<u>Style 1</u>:

The Effect of Sunlight on Height of Plants

I.V. Sunlight (hrs)	D.V. Height of Plants (cm) Trials												Statistics	
													Central Tendency	Spread
	1	2	3	4	5	6	7	8	9	10	11	12	Mean	Range
0														
12														
24														

Style 2:

Title: The Effect of Sunlight on Height of plants			
D.V. (unit) Height of Plants (cm)	**I.V. (unit)** Sunlight(hrs)		
Trials:	0	12	24
Mean			
Range			
Standard Deviation			

CHECKLIST FOR EVALUATING DATA TABLES:

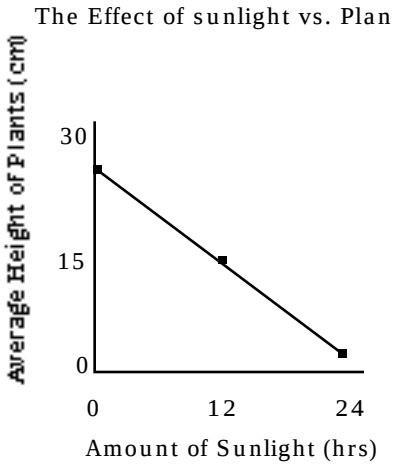
1. Title			
2. Vertical column for I.V.			
3. I.V. Variable and Unit			
4. Vertical Column for D.V.			
5. D.V. and Unit for D.V.			
6. Trials listed properly			
7. Data correctly entered			
8. Columns/Rows for Statistics			
9. Statistics correctly calculated			

STATISTICS: There are 3 derived quantities or statistics we will calculate for our data: mean, range, and standard deviation.

1. **MEAN** - is the average of the data. Mean is calculated by adding all the data for a particular level and dividing by the number of trials. The **Central Tendency** of the data.
2. **RANGE** - is the spread of the numbers within a particular level. Range is calculated by subtracting the lowest value from the highest value. The **Spread** of the data.
3. **STANDARD DEVIATION** - is more complicated. It is somewhat the average of the averages. We will use a statistical calculator to calculate this number. Another way to calculate the **Spread** of the data.

GRAPH: sometimes, you may not be sure whether to make a bar graph or a line graph of your data. The appropriate type of graph depends on the type of data collected.

A. **LINE GRAPH:** Use when the I.V. is a continuous range of measurements with equal intervals. When the I.V. is numerical and the intervals between the numbers have meaning, such as height of plants, amount of fertilizer, length of time, submersion time.



As the amount of sunlight increases, the height of the plants decreases.

HOW TO DETERMINE SCALES FOR X AND Y AXES AND DRAW A LINE-OF-BEST FIT:

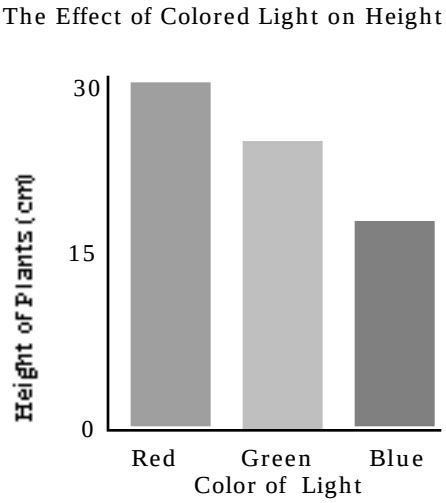
The most challenging part of constructing graphs is determining the right scale for numbering the axes of a graph. An easy way to find a good scale to fit the data consist of a series of steps described in the following:

Steps: (1) Label X axis with the I.V. Include a unit if applicable.
(2) Label Y axis with the D.V. Include a unit if applicable.
(3) Calculate intervals for Numerical data.
a. Find the range of data to be graphed.
b. Divide this number by 5, 6 or 6. This will result in 5-7 intervals)
c. After dividing, round the number to the nearest convenient counting number. (2, 5, 10)
(4) Plot data and draw a line of best fit. A **line of best fit** goes through as many points as possible, leaving even numbers of leftover points on each side of the line.

CHECKLIST FOR EVALUATING LINE GRAPHS:

1. X Axis correctly labeled including units						
2. Y axis correctly labeled including units						
3. X axis subdivided in appropriate scale						
4. Y axis subdivided in appropriate scale						
5. Data pairs correctly plotted						
6. Data trend summarized with line-of-best-fit						
7. Data trend summarized (Results Sentence)						
8. Title (The Effect of I.V. on D.V.)						

BAR GRAPH: Use when the I.V. is categorical. There is not standard numerical scale and the intervals have no numerical meaning, such as days of week, color, brand names.



Plants reach their greatest height under red light, and their least height under blue light.

CHECKLIST FOR EVALUATING BAR GRAPHS:

1. X axis correctly labeled including units						
2. Y axis correctly labeled including units						
3. X axis correctly subdivided - discrete values						
4. Y axis correctly divided into scale						
5. Vertical bars for data pairs correctly drawn						
6. Data trend summarized with sentences (Results Sentence.)						
7. Title (The Effect of I.V. on D.V.)						

HOW TO WRITE A RESULTS SENTENCE: The Results Sentence states is a simple sentence stating what **actually** happened in the experiment, even if it is not what was expected in your hypothesis. It usually starts with the word **As**. First the I.V. is summarized and then the D.V. is summarized. Sometimes the usual format can't be followed because the results were unexpected. Every result that occurred should be mentioned.

As the I.V. is (increased or decreased), **the D.V.** (increased or decreased.)

Example: From Line Graph above: As the amount of sunlight increased, the height of the plants decreased.

From the Bar Graph above: Plants reach their greatest height under red light, their least height under blue light.

SUMMARY PARAGRAPH:

A **Summary Paragraph** is a presentation of the results of the experiments in word form, rather than in tables and graphs. Usually the following questions are presented in paragraph form:

1. Write a topic sentence stating the independent and dependent variables, and a reference to tables or graphs.

Format: The (Insert Title) are summarized and presented in the above (table, graph etc.)

Example: Effects of stress on the height of bean plants are summarized and presented in the above table and graph.

2. Write sentences comparing the measures of central tendency (mean or mode) and spread (standard deviation or range) of the groups. **Include statistical numbers** showing mean and range.

Example: Stressed plants exhibited a greater mean height (60 cm) than non-stressed plants. (56.0 cm). Variations within the groups were similar, with stressed plants having a standard deviation of 7.0 and non-stressed plants a standard deviation of 7.8. Ninety-five percent of the stressed plants fell within the range of 46.0 to 74.0 as opposed to non-stressed plants that ranged from 40.4 to 71.6.

3. Write sentences stating support (or non-support) of the hypothesis by the data. Restate the hypothesis in the sentence.

Example: The data did not support the hypothesis that stressed plants would have a lower height after planting than non-stressed plants.

CHECKLIST FOR EVALUATING A SUMMARY PARAGRAPH:

1. Purpose of experiment? Hypothesis restated?							
2. Central tendency discussed? Numbers included?							
3. Spread discussed? Numbers included?							
4. Support of hypothesis discussed?							

CONCLUSION PARAGRAPH:

A **Conclusion Paragraph** usually contains a description of the purpose of the experiment, a discussion of your major findings, an explanation of your findings, and recommendations for further study. Usually the following questions are presented in paragraph form:

1. What was the purpose of the experiment? (Include I.V. and D.V. in this sentence.)

Format: The purose of the experiment was to investigate (Insert Title.)

Example: The purpose of the experiment was to investigate the effect of stress on the growth of bean plants by comparing the growth of bean plants subjected to stress for 15 days with a control (non-stressed plants.)

2. What were the major findings?

Format: The major findings were (Insert Results Sentence.)

Example: The major findings wer e that there was no significant difference existed between the mean height of stressed plants and non-stressed plants 30 days after transplanting.

3. Was the hypothesis supported by the data?

Format: The hypothesis that (Insert Hypothesis) was (supported, partially supported, or not supported.)

Example: The hypothesis that stressed plants would have a lower mean height was not supported.

4. How did your findings compare with those of researchers?

Example: In contrast, Japanese farmers found that hitting and pulling rice plants were beneficial to plant height.

5. What happened that you did not expect? How can you explain this?

Format: I did not expect (Insert anomaly if there was one.) I can explain this (insert explanation.)

Example: The stressed bean plants were expected to have a lower height. the fact that they didn't and that Japanese rice farmers stress their points on purpose to achieve better growth means that something about stressing out plants makes them growth better. Perhaps some plants that are stressed release a chemical in response to the stress that promotes better growth and others don't release that chemical, such as rice vs. beans. Or perhaps there is a difference in reaction to stress between monocots and dicots.

6. What recommendations do you have for improving this experiment?

Example Improved experimental design techniques including a larger sample and a longer growing period would benefit a similar study.

7. What recommendations do you have for further study? (This is above and beyond this experiment.)

Example: Additional investigations using various sources of stress at more frequent intervals would be a good additional experiment. another idea would be to use different types, such as a monocot and a dicot. If further research were done, perhaps scientists have isolated a chemical released by plants during stress. It would be interesting to investigate the amounts of this chemical released during stress.

CHECKLIST FOR EVALUATING A CONCLUSION PARAGRAPH:

1. Purpose of experiment?							
2. Major findings?							
3. Support of hypothesis by data?							
4. Comparisons?							
5. Explanations?							
6. Recommendations for improvement?							
7. Recommendations for further study?							