Classroom Instruction That Works

Module 8: *Generating & Testing Hypotheses*

Instructor Resource Packet

What message would you put in a time capsule to be opened by your descendants in 100 years? Assume that we have not destroyed our planet by then, of course. We are thinking positive here. Do you have advice? An admonition? Or would you make them laugh? Write your message on the back of the paper.

http://adulted.about.com/od/icebreakers/qt/timecapsule.htm

sampler

Hypothesis-based learning

Venture into my seventh-grade classroom on any given day, and you are likely to see students hypothesizing, designing experiments to test their explanations, analyzing data, writing formal publications of results, and debating over scientific procedures in an attempt to justify their control of variables. Students are motivated, on-task, begging for more class time, and learning an enormous amount of scientific concepts. This is hypothesis-based learning (HBL).

What is HBL?

HBL starts with observation. In the classroom, the teacher sets up an initiating event for students to carry out and record observations. As soon as the students see something that they didn't expect (discrepant event), they propose an explanation (hypothesis). Students then design a test of their explanation and predict the outcome. They conduct their test, analyze their results, and form conclusions. The students are in the driver's seat. The teacher assesses whether or not each student follows the scientific process while the students are given the freedom to test their own ideas. HBL mirrors what we all naturally do, and this is the same process that scientists have continued to use in the laboratory.

I decided to try HBL and began with a static electricity investigation called Sticky Tape (see Resources). To begin, students removed two 10 cm strips of transparent tape from a roll. Nonsticky handles were created by folding over 1 cm at the end of each tape back onto itself. One strip was then laid flat, sticky side down, on the top of a lab table. The second piece was then laid atop the first piece, sticky side down. Both pieces were then peeled off the table surface together. When students peeled the two apart by the handles, the pieces became charged, one with a negative charge, the other with a positive. Students quickly discovered that if the two strips were brought close together, they were pulled toward one another.

For the next few minutes, students moved around the room exploring the charges of different objects. It was fun to watch them test the charges on everything from the walls to each other. While all this was going on, I was left standing in the middle of the room scratching my head, thinking, "Now what?" Students were fascinated by the fact that the tapes would bend toward some objects and away from others, but I was frustrated because I failed to recognize beforehand that my students had no idea how to actually use the scientific process**.** Before we could really conduct an HBL experiment, I had to first teach students how to function as scientists. HBL teachers use templates to guide their students as they work through the process (see Figure 1).

The beauty of HBL

At the beginning of the next school year, I spent more time teaching my students just how to observe. Once they became keenly observant, explanations for different phenomena began to form without hesitation. Occasionally the students would encounter a topic that was unfamiliar, and they were afraid to hypothesize for fear of being "wrong." However, with HBL, students are taught that a hypothesis is never right or wrong; it is either supported or unsupported by analysis of the experiment. Students have to be encouraged to bring everything they know to the surface to form an explanation.

A powerful component of HBL is the wrap-up. After students have completed their experiments, they are instructed to analyze their data and write a formal report. The formal report helps them to organize their thoughts and review their work. The teacher then brings together all of the different student experiments and ties in scientific concepts. Students feel a sense of accomplishment when as their work is mentioned, and the importance of their experiment is displayed for their peers as the teacher presents science principles inferred from what they observed. After the wrap-up, students can read textbooks, websites, or other resources for additional information. The teacher places heavy emphasis on tying all of their work back to science concepts. As a result, curriculum standards are met, and students are interested in the lecture because they are learning more about their own experiences. They retain the concepts because they were motivated to learn about them in the first place. HBL isn't just "hands-on" or science inquiry. This teaching method shows students how to truly function as scientists. Through this method they begin to asborb and retain a tremendous amount of scientific knowledge.

Journey through the scientific process

- First stop: Observe. Record both qualitative and quantitative information.
- Second stop: Explain. What is your explanation for something that you observed that you did not expect? This is your hypothesis!
- Third stop: Fair test. Write in one sentence how you will test your explanation.
- Fourth stop: Predict. Write what you expect for the outcome of your test.
- Fifth stop: Experiment procedure. List the steps you will follow during your experiment.
- Sixth stop: Variable control. State your independent and dependent variables. Also, write about what other possible variables could occur that you will control (keep constant) in order to ensure a fair test.
- Seventh stop: Data. Create a data table to record information during your experiment.
- Eighth stop: Results. What happened during your experiment?
- Ninth stop: Analysis and conclusions. What did you learn? Create a graph or visual to help you analyze your experiment. Did your predicted outcome occur? Is your hypothesis supported or unsupported? Do you need to revise your hypothesis? What would you do differently next time?
- Tenth stop: Communication. What will you tell others about your experiment? What contributions can be made based on what you have learned from your work?

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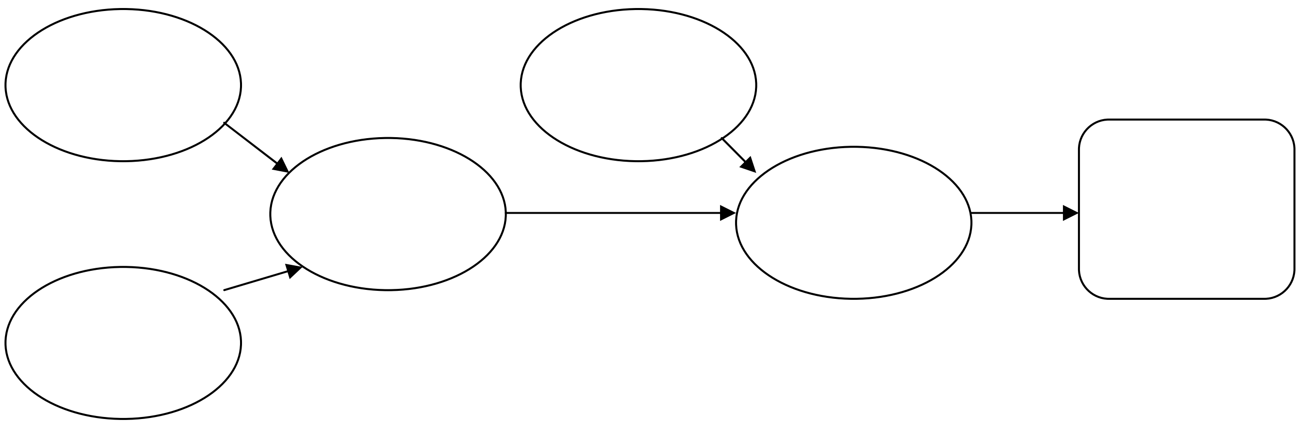
Acknowledgments

Thanks to Mark Rockley and Bruce Ackerson, Oklahoma State University, for their encouragement to publish, and for their devotion to improving science education through HBL.

Resources

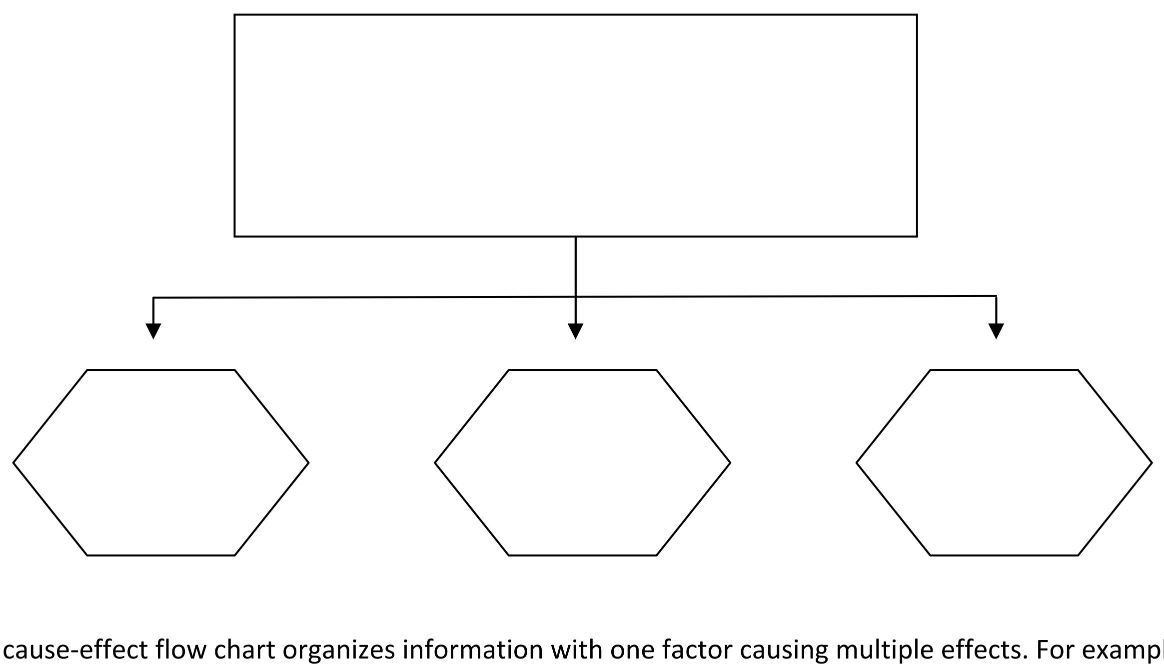
Many versions of the Sticky Tape activity can be found in activity books and on the web. I recommend the version found at the HBL, www.HbL4u.org. Many other HBL-based activities are available at this site.

Process/Cause-Effect Pattern Organizer



Process/Cause-Effect patterns organize information into a network leading to a specific outcome or into a sequence of steps leading to a specific product. For example, information about the factors that typically lead to the development of a healthy body might be organized using the pattern organizer and represented graphically as shown above.

Cause-Effect Flow Chart

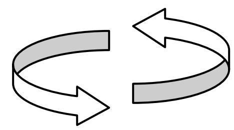


The cause-effect flow chart organizes information with one factor causing multiple effects. For example, stress may cause a variety of adverse effects.

Root Cause Analysis

FIND IT—Diagnostic Phase

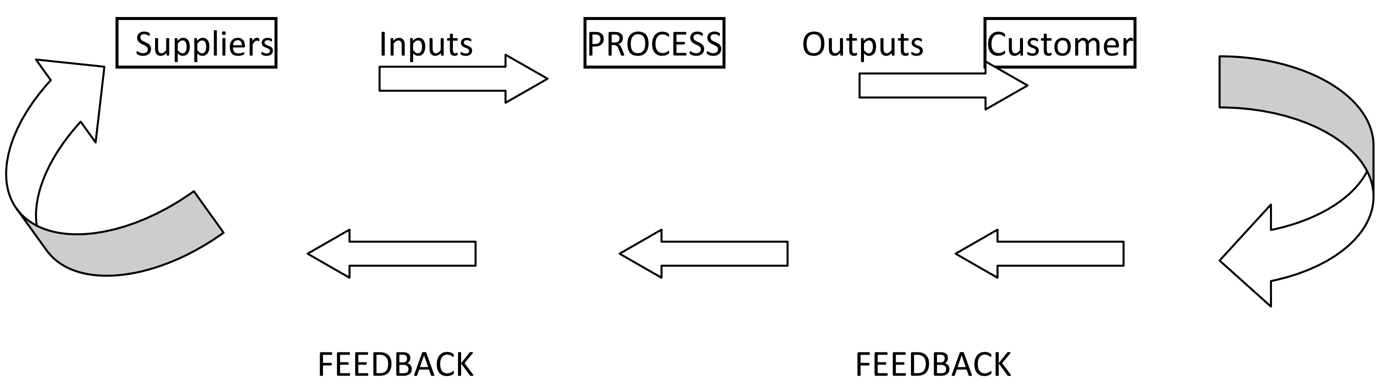
1. Define the Problem
2. Understand the Process = Flow Chart = SIPCO*
3. Identifying Possible Causes
4. Collect Data
5. Analyze the Data



FIX IT—Solution Phase

6. Identify Possible solutions
7. Select Solutions to be Implemented
8. Implement the Solutions
9. Evaluate the Effect
10. Standardize the Process

SIPCO



Lab Sheet A

Title	
Problem Statement (copied from board)	**Hypothesis** (written or drawn)
Materials (listed or drawn)	**Procedure** (class discussion Step-by-step)
Observations (written or drawn)	**Data/Graph**
Results (class discussion or written)	**Conclusion** (class discussion or written/drawn)

Lab Sheet A (filled example)

<table>
<tr><th colspan="2">Heat it Up!</th></tr>
<tr><td>Problem Statement (copied from board)

What effect does color have on heat absorption?</td><td>Hypothesis (written or drawn)

Black White Aluminum</td></tr>
<tr><td>Materials (listed or drawn)

3 aluminum cans
Black paint
White paint
Scissors
Thermometers</td><td>Procedure (class discussion Step-by-step)</td></tr>
<tr><td>Observations (written or drawn)

90 76 80

Black White Aluminum</td><td>Data/Graph

Black White Aluminum</td></tr>
<tr><td>Results (class discussion or written)</td><td>Conclusion (class discussion or written/drawn)</td></tr>
</table>

Lab Sheet B

Name ________________________________ Date ____________________

Activity Title: A short, creative, catchy phrase (*Example:* ***Heated Up***!)

Problem Statement: What problem are we going to investigate? **(***Example: What effect does color have on heat absorbency?)*

Hypothesis: Make a guess on what you think will happen. *(Example:* ***If*** *aluminum cans are painted various colors and placed under a heating lamp* ***then*** *the darker colored aluminum can will absorb more heat.)*

Constant Variables *(Ex. Aluminum Cans, type of paint, time exposed to heat)*	**Manipulated Variable** *(Ex: Aluminum can painted black, Aluminum can painted white)*	**Responding Variable** *(Ex.: Temperature within the aluminum can)*

Materials: **(**Make sure you have all the correct items for this experiment.)
Procedure: **(**Conduct your experiment, following the steps exactly as given**.)**
Data Collected: **(**Label the shaded areas**)**

Results: What happened in the experiment?

(Example: The temperature of the black can was 85° C after five minutes. The temperature of the white can was always 5°C less that the black can.)

Conclusion: Was your hypothesis (guess) correct? Why or why not?

(Example: My hypothesis can be accepted because the black aluminum can absorbs more heat than the unpainted can and the white can.)

Application: What did you learn?

(Ex.: This project can be applied to selecting the proper clothing for winter vs. summer months.)

Observations/Drawings:

Lab Sheet C

Activity Title: A short, creative, catchy phrase (*Example:* ***Heated Up***!)

Problem Statement: The problem that needs to be solved. **(***Example: What effect does color have on heat absorbency?)*

Hypothesis: a prediction or educated guess. *(Example:* ***If*** *aluminum cans are painted various colors and placed under a heating lamp* ***then*** *the darker colored aluminum can will absorb more heat.)*

Control Variable (Ex. Unpainted Aluminum Can)	**Manipulated Variable** (Ex. Aluminum can painted black, Aluminum can painted white)	**Responding Variable** (Ex.: Temperature within the aluminum can)

Fixed Variables: All the things that will remain the same.

(Example: The size of the can, the type of thermometer, the distance of the cans from the lamp, the type of paint, etc.)

Results: Specific outcomes of the experiment

(Example: The temperature of the black can was 85° C after five minutes. The temperature of the white can was always 5°C less that the black can.)

Conclusion: What was learned.

(Example: My hypothesis can be accepted because the black aluminum can absorbs more heat than the unpainted can and the white can.)

Application:

(Ex.: this project can be applied to selecting the proper clothing for winter vs. summer months.)

Activity Title:

Procedure (List as steps and be specific):

Example: Peel the label off of several aluminum cans.

Step 1:	
Step 2:	
Step 3:	
Step 4:	
Step 5:	
Step 6:	
Step 7:	
Step 8:	
Step 9:	
Step 10:	
Step 11:	
Step 12:	

Activity Title:

Materials (Be specific):

List of Materials *(Example: three Celsius thermometers)*	**Intended use** *(Example: To measure the temperature of three aluminum cans)*
1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	
9.	
10.	
11.	

Activity Title:

Data Collected: (Label the shaded areas)

Graph Title

Units

Y – axis Label

X-axis Label

Units or Graph Key

Data Table and Graph

Observations:

Drawings:

Lab Report Materials developed by:

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Scientific Method

(Materials developed for Middle School students)

Compiled by Dr. Debra Allen, Curriculum Support Specialist, Regional Center II

Student Name__________________________________ Date _______________

Planning

What are you going to investigate? (*Problem Statement or Research Question)*

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What do you think will happen? Explain why. *(Hypothesis or Prediction)*

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Which variable are you going to:

- change? ____
  (Independent Variable) ____
- measure or observe? ____
  (Dependent Variable) ____
- keep the same? ____
  (Constants) ____

How will you make it a fair test? (What variables are you going to keep constant and what is the only variable you will change? Are you going to set up a control experiment? Explain.)

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What equipment and materials will you need? *(Materials)*

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How will you carry out this investigation? (*Procedure* – List in steps)

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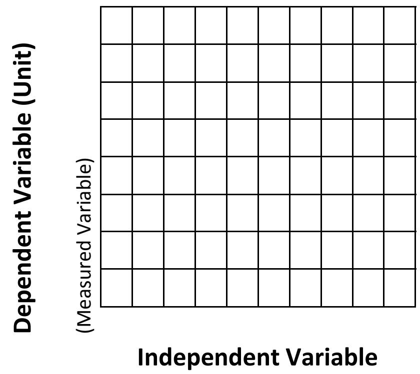
Data and Results

Can your results be presented in a table?

Variable Changed (Independent Variable)	Variable Measured (Unit) or Observed (Dependent Variable)			
	Trial 1	Trial 2	Trial 3	Mean

Can the data from your table be presented as a graph?



What happened? Describe your observations and your data.

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Conclusion

1. What was investigated? (Describe the problem statement)

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2. Was the hypothesis supported by the data?

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3. What were the major findings?

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4. How did your findings compare with other researchers?

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5. What possible explanations can you offer for your findings?

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6. What recommendations do you have for further study and for improving the experiment?

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7. What are some possible applications of the experiment?
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Title: ____

Independent Variable | **Dependent Variable (Unit)**

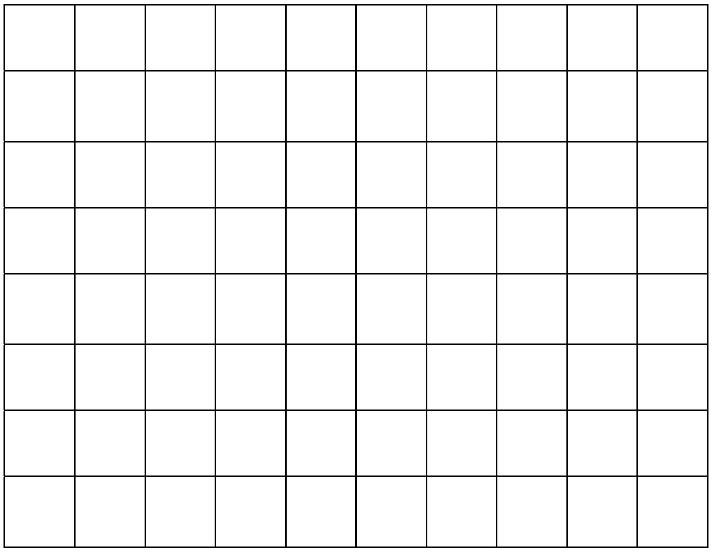
(Variable Measured or Observed)

	Trial 1	Trial 2	Trial 3	Mean

BAR GRAPH

Title: ____

Dependent Variable (Unit)



Specific Labels →

General Label →

Independent Variable

Title: ____

Independent Variable

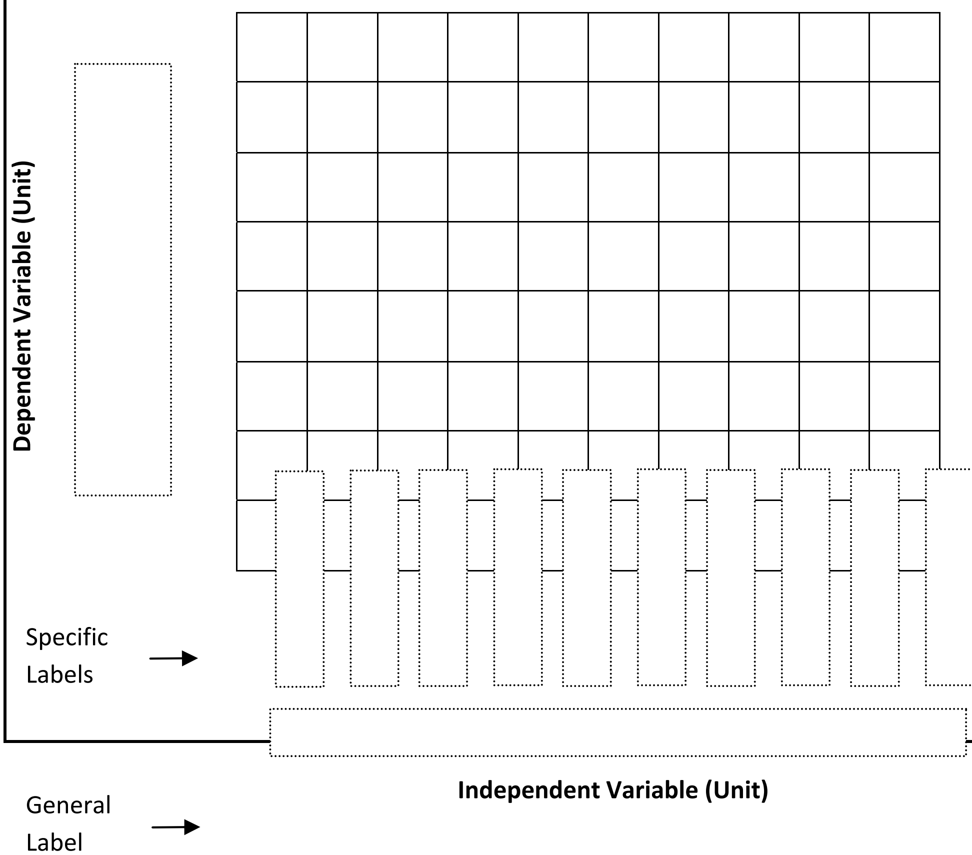
Dependent Variable (Unit)

(Variable Measured or Observed)

	Trial 1	Trial 2	Trial 3	Mean

LINE GRAPH

Title: ____



Power Writing and the Art of Scientific Conclusions

Contributed by M-DCPS Curriculum and Instruction, Science

With the onset of the Florida Comprehensive Assessment Test (FCAT) in mathematics, reading, writing, and science, it is imperative that schools take steps to prepare students for this battery of tests that will extend from grade three to grade eleven. Schools will a grade and a level of achievement from the State of Florida based on how well they perform on this assessment process.

It is logical and inevitable that preparation for this testing will involve the entire instructional staff of schools in every subject area to insure maximum levels of student achievement at each grade level. Interconnections among instructional strategies in individual subject areas with respect to performance tasks and problem solving can serve to strengthen student performance on the FCAT. The students will receive more preparation for this testing if it is reinforced, in every class they take through activities that familiarize them with the style of questioning they are likely to see on the tests. The effect is potentially synergistic.

Writing scientific conclusions for laboratory investigations has always been one of the more challenging tasks for science students to do and for science teachers to grade. The Power Writing Model used in language arts instruction contains many similarities to good scientific conclusion writing.

Power Writing Vocabulary as correlated to a Scientific Conclusion

Introduction: What you will prove and how you will prove it. A problem statement combined with a working hypothesis/trial solution.

Thesis statement: The single point of the entire essay (Problem to be solved).

Topic Sentence: The single point of a paragraph (In science the topic sentence varies with respect to the introductory, middle, and concluding paragraphs).

General Statement: One way to prove the topic sentence is true (supported or not supported). This is a general statement that is supported or not supported by the data collected and that will answer one of the seven questions that must be addressed when writing scientific conclusions.

Proof: Portion of investigation that addressed each question to be answered in a conclusion. It will be in the form of data collected that has been analyzed and interpreted to determine the findings that will or will not support the hypothesis that has been tested.

Commentary: Opinion (inference or inferences made based on the data collected).

Concluding Sentence: One statement that is true (supported or not supported) for all the proof in the paragraph; opinion (inference).

Concluding Paragraph: Statements that are true (supported or not supported) for all the proof in the entire essay; opinion (inferences).

Organization: All essays and all paragraphs have a beginning, middle, and an end. All scientific conclusions answer the seven basic questions that must be addressed when conducting complete scientific investigations.

Power Writing in Science

Introductory Paragraph:

State what you will prove. In science conclusions, you would write the problem statement in the form of a question. You would then write your hypothesis that is the trial solution you have selected (this takes care of **question 1**). You are stating the ways you have proved your trial solution to be either supported or not supported by answering **question 2**. This is how the rest of the sentences in the introductory paragraph are linked. They will describe the data that was collected and the major findings of the investigation (**question 3**) that supported or did not support the hypothesis as the solution to the restated problem.

Body Paragraphs:

The body paragraphs support the introductory paragraph by elaborating on the different pieces of information that were collected as data that either supported or did not support the original hypothesis. Using terms such as “as a matter of fact” or “for example” and “not only but also” for successive sentences is useful. Each finding needs its own sentence and relates back to supporting or not supporting the hypothesis. The body paragraphs may include **question 4**, which describes how the findings compared with other researchers or groups investigating the same problem. The number of body paragraphs you have will depend on how many different types of data were collected. They will always refer back to the findings in the first paragraph. The concluding sentence can begin with a term such as “clearly” which would be followed by the statement that is true (support or non support) for the entire paragraph as it relates to the hypothesis. The commentary can include some inferences (opinions) although the major inferences should be reserved for the concluding paragraph.

Concluding Paragraph:

The concluding paragraph contains the major commentary about the problem statement and the hypothesis in the first paragraph of the conclusion. This is where **question 5** can be answered. The paragraph should also include answers to **questions 6 and 7** that include what recommendations you have for further study and for improving the experiment and some possible applications of the experiment. At the end of the paragraph the problem statement and hypothesis (introduction and thesis) is restated more specifically with an abbreviated version of the explanation of the findings to summarize the conclusion.

Conclusion Questions:

1. **What was investigated?** (Describe the problem statement): The relationship between the age of compost used in soil and the growth, health, and quality of the leaves of tomato plants were investigated.

2. **Was the hypothesis supported by the data?**: The data appears to support the hypothesis that the growth, health, and leaf quality of tomato plants would improve with increases in the age of compost mixed with soil.

3. **What were the major findings?**: As the age of the compost increased the health, quality of the leaves, and the mean height of the tomato plants increased. The mean height of plants grown in soil with compost aged for six months was greater than the control group, with plants exhibiting similar health. More plants grown in soil with six month-old compost exhibited poor leaf quality than in the control.

4. **How did your findings compare with other researchers?**: No similar studies were found relating the age of compost to the growth of tomato plants.

5. **What possible explanations can you offer for your findings?**: As the compost decomposes, nutrients needed by the plant may be released thereby improving the growth of the plant.

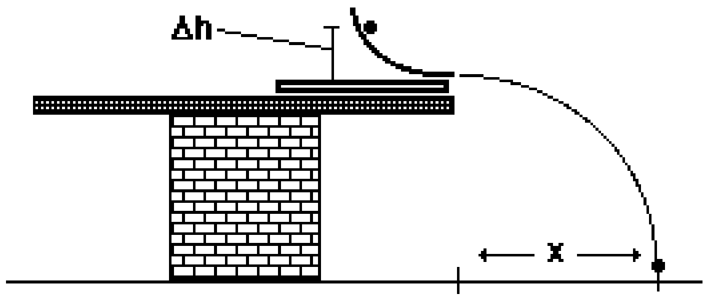
6. **What recommendations do you have for further study and for improving the experiment?**: This experiment could be repeated with an increased number different ages of compost. Measurements of soil temperature may help to understand what is happening to the compost.

7. **What are some possible applications of the experiment?**: The use of compost aged for longer than six months will improve the growth of tomato plants.

Writing the Lab Report

Labs are the basis for our understanding of the key concepts in physics. What follows are the guidelines for success in writing a quality lab report.

1. You should keep all data collected during the lab on loose-leaf paper in the physics section of the Study Skills binder.
2. All laboratory reports are to be written in pen on loose-leaf paper or word-processed on one side only.
3. Your name, the name(s) of all members of your laboratory team and the date the investigation was performed is to be written in the upper right hand corner of the first page of each report.
4. An appropriate title for the report should be placed in the center of the first page of the report.
5. Each of the following sections of the laboratory report should be prefaced with the section names.

Purpose	This is a statement of the problem to be investigated. It provides the overall direction for laboratory investigation and must be addressed in the conclusion.
Apparatus	All laboratory apparatus used in the investigation, along with a detailed diagram to illustrate the configuration of the apparatus, should be included in this section. See example below. The variables to be measured should be clearly pictured. 
Procedure	This section should identify and name all experimental variables and briefly describe how the independent variables are controlled. Someone who was not present during the lab should be able to understand how to perform the experiment by your procedure.
Data	Data consists only of those values measured directly from the experimental apparatus. No values obtained by way of mathematical manipulations or interpretations of any kind may be included in this section of the report. Data should consist of as many trials as judgment would indicate necessary. The units for physical measurements (kg, m, s, etc.) in a data table should be specified in column heading only.
Evaluation Of Data	This section should include all graphs, analysis of graphs, and post laboratory calculations. State each formula, and if necessary, identify the symbols used in the formula. If repetitive calculations are to be performed, substitute only one set of data into each formula and then construct a **table of values** for all additional calculated values. Be certain that your final calculated values are expressed to the correct number of significant figures. Do not show your arithmetic calculations.
Conclusion	In the conclusion you must; **a)** state the relationship between the variables identified in the purpose in a clear, concise English sentence; **b)** (when appropriate), state the meaning of the slope, area under the curve, and discuss the significance of the **y-**intercept, and write the mathematical expression derived from graphical analysis with the appropriate units; **c)** describe any new terms that arise as a result of your evaluation of data; and **d)** when your results differ from what is expected, provide a plausible explanation.

Parts of a Lab Report
A Step-by-Step Checklist

Good scientists reflect on their work by writing a lab report. A lab report is a recap of what a scientist investigated. It is made up of the following parts.

<u>Title (underlined and on the top center of the page)</u>

<u>Benchmarks Covered:</u>

- Your teacher should provide this information for you. It is a summary of the main concepts that you will learn about by carrying out the experiment.

<u>Problem Statement:</u>

- Identify the research question/problem and state it clearly.

<u>Potential Hypothesis(es):</u>

- State the hypothesis carefully. Do not just guess; instead try to arrive at the hypothesis logically and, if appropriate, with a calculation.
- Write down your prediction as to how the independent variable will affect the dependent variable using an "if" and "then" statement.
  - ❖ If <u>(state the independent variable)</u> is <u>(choose an action)</u>, then <u>(state the dependent variable)</u> will <u>(choose an action)</u>.

<u>Materials</u>:

- Record precise details of all equipment used.
  - ❖ For example: a balance that measures with an accuracy of +/- 0.001 g.
- Record precise details of any chemicals used.
  - ❖ For example: (5 g of $CuSO_4 \cdot 5H_2O$ or 5 g of copper (II) sulfate pentahydrate).

<u>Procedure:</u>

- Do not copy the procedures from the lab manual or handout.
- Summarize the procedures; be sure to include critical steps.
- Give accurate and concise details about the apparatus and materials used.

<u>Variables and Control Test</u>:

- Identify the variables in the experiment. State those over which you have control. There are three types of variables:
  1. <u>Independent variable</u> (also known as the manipulated variable): The factor that can be changed by the investigator (the cause).
  2. <u>Dependent variable</u> (also known as the responding variable): The observable factor of an investigation that is the result or what happened when the independent variable was changed.
- <u>Constant variable:</u> The other identified independent variables in the investigation that are kept or remain the same during the investigation.
- Identify the control test. A control test is the separate experiment that serves as the standard for comparison to identify experimental effects and changes of the dependent variable resulting from changes made to the independent variable.

Data:

- Ensure that all data is recorded.
  - ❖ Pay particular attention to significant figures and make sure that all units are stated.
- Present your results clearly. Often it is better to use a table or a graph.
  - ❖ If using a graph, make sure that the graph has a title, both axes are labeled clearly, and that the correct scale is chosen to utilize most of the graph space.
- Record all observations.
  - ❖ Include color changes, solubility changes, whether heat was evolved or taken in, etc.

Results:

- Ensure that you have used your data correctly to produce the required result.
- Include any other errors or uncertainties that may affect the validity of your result.

Conclusion and Evaluation:

A conclusion statement answers the following seven questions in at least three paragraphs.

I. First Paragraph: Introduction

1. What was investigated?
   a) Describe the problem.
2. Was the hypothesis supported by the data?
   a) Compare your actual result to the expected result (either from the literature, textbook, or your hypothesis).
   b) Include a valid conclusion that relates to the initial problem or hypothesis.

II. Middle Paragraphs: These paragraphs answer question 4 and discuss the major findings of the experiment, using data.

1. What were your major findings?
   a) Did the findings support or not support the hypothesis as the solution to the restated problem?
   b) Calculate the percentage error from the expected value.
2. How did your findings compare with other researchers?
   a) Compare your result to other students' results in the class.
      - The body paragraphs support the introductory paragraph by elaborating on the different pieces of information that were collected as data that either supported or did not support the original hypothesis.
      - Each finding needs its own sentence and relates back to supporting or not supporting the hypothesis.
      - The number of body paragraphs you have will depend on how many different types of data were collected. They will always refer back to the findings in the first paragraph.

III. Last Paragraph: Conclusion

1. What possible explanations can you offer for your findings?
   a) Evaluate your method.
   b) State any assumptions that were made which may affect the result.
2. What recommendations do you have for further study and for improving the experiment?
   a) Comment on the limitations of the method chosen.
   b) Suggest how the method chosen could be improved to obtain more accurate and reliable results.
3. What are some possible applications of the experiment?
   a) How can this experiment or the findings of this experiment be used in the real world for the benefit of society?

Template

Title: ____)

Benchmarks Covered:

____
____
____

Problem Statement:

____
____
____

Potential Hypothesis(es): (state the dependent and independent variable)

____
____
____

Materials:

____
____
____
____

Procedure: (Do not copy the procedure, summarize it)

____
____
____
____

Variables and Control Test: (Dependent, independent, and constant)

____
____
____
____

Data tables:

Class Results Table:

Data Analysis:

Insert graphs and statistical analysis

Results:

- Ensure that you have used your data correctly to produce the required result.
- Include any other errors or uncertainties that may affect the validity of your result.

<u>Conclusion and Evaluation</u>:
(A conclusion statement answers the following seven questions in at least three paragraphs.)
Introduction (What was investigated? Was the hypothesis supported by the data?)

Middle Paragraphs: (These paragraphs answer question 4 and discuss the major findings of the experiment, using data.)(What were your major findings? How did your findings compare with other researchers?)

Last Paragraph: Conclusions (What possible explanations can you offer for your findings? What recommendations do you have for further study and for improving the experiment? What are some possible applications of the experiment?

Articles on Shakespeare

1. "Who was Shakespeare?"
   http://news.bbc.co.uk/cbbcnews/hi/find_out/guides/showbiz/shakespeare/newsid_3539000/3539058.stm

2. "Did Shakespeare really exist?"
   http://news.bbc.co.uk/cbbcnews/hi/find_out/guides/showbiz/shakespeare/newsid_3538000/3538936.stm

3. "'Shake-scene' and shattering the Shakespeare myth: a question for Daryl Pinksen"
   Nov. 24, 2008 http://marlowesghost.com/commentary

4. "Who was Robert Poley? A Question for Daryl Pinksen, author of Marlowe's Ghost"
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