



CoursePak for lab experiments designed by students

Description: The following documents provide you with a packet of all core LabWrite materials you can print or use in PDF format. Note that the Resources page included here only contains a list of LabWrite Resources. If you want a particular resource, you'll have to go to the Resources homepage and print it.

Designing Experiments SelfGuide

Printable Version

PreLab: questions to answer before doing the lab

1. What is the problem? Describe the problem in your own words. Be sure that your description includes **known factors** (information about the problem given to you in the lab in a problem statement, for example) and **unknowns** (what you need to find out in order to solve the problem). Then restate the problem in the form of a question or questions that will guide your research.

Example:

Background for the experiment:

Lori is on her school's volleyball team. Because she and her teammates spend a lot of time doing jumping exercises, she has become interested in the standing vertical leap, which plays an important role not only in volleyball but also in basketball. Lori knows that success in both sports depends to a large extent on an athlete's ability to jump higher than opposing players. She wants to design an experiment in biomechanics that will help her determine what jumping strategies athletes can use to jump their highest.

What is the problem?

The standing vertical jump plays a critical role in several sports, especially volleyball and basketball. In volleyball, players must spike the ball and block spikes by the opposing team by leaping from a standing position. In basketball, players often shoot under the basket and rebound from a standing position. In both sports, the effectiveness of the players can be increased by being able to jump higher. The problem, though, is that many players don't know how to make the best use of biomechanics to jump their highest. This is an experiment that I hope will provide information that can help athletes, including myself, jump higher.

What I know is that there are, generally speaking, two approaches to vertical jumps from a standing position. The first is called the squat jump. You begin the jump in a modified crouch or squat with the knees bent and then spring from that position. In the other approach to jumping, you begin the jump with a downward movement of the body and arms that leads to an upward spring. The unknown is which of these two approaches allows the jumper to jump higher.

My question is: Which of these two approaches to the vertical standing jump, the squat jump and the countermovement jump, provides the biomechanics that result in a higher jump?

2. What do you know about the science of the problem that could help you answer your research question? State the [scientific concept](#) (see below for definition) that the lab is about (something like the quantization of energy, photosynthesis, or momentum conservation). Write down information you can find about the concept that might be useful in answering your research question (check lab manual, textbook, class notes, handouts, etc.). Note any citations of sources you use. Go to [Citations and References](#) under Resources of the web version of this document for more help.

Scientific Concept:

Most science labs are designed to help you learn about a scientific concept. If you are having trouble identifying the scientific concept this lab is about, check the title of the lab in the lab manual and read the introduction to the lab in the manual. It will be

something like photosynthesis, quantization of energy, or momentum conservation.

Write down the scientific concept. Then write down what you know about the concept based on the lab manual, textbook, class notes, and handouts. Don't try to make it pretty; just keep writing. Get as much down as you can. Because the point of the lab is to learn about the scientific concept, it's important to state what you already know.

Example:

What do you know about the science of the problem that could help you answer your research question?

I found a web site and an article that helps me to understand the standing vertical jump. The scientific concept involved in understanding the standing vertical jump is Newton's third law of motion: for every action, there is an equal and opposite reaction. Basically, when a person jumps, she is overcoming her body weight, the force of gravity that holds her on the ground. The jumper applies force against the surface she is jumping from and that force results in the equal and opposite reaction of resisting gravity by elevating off the jumping surface.

Thus, the height of a jump may be understood in terms how much force is exerted against the jumping surface. Height is a function of acceleration, velocity, and time: how much time the jumper is in the air depends on the acceleration and speed of the jump. The greater the force against the jumping surface, the greater the acceleration and velocity of the jump and the longer the jumper is in the air. The length of time in the air correlates to the height of the jump—"hang time." Thus, acceleration/velocity/time are key to the height of the jump. What this scientific concept suggests is that the biomechanics of a jumper that allow the jumper to apply the greatest force against the jumping surface will lead to the highest jump.

3. What is your hypothesis for the answer to your research question? Using what you know about the problem and the scientific concept of the lab, state a [hypothesis](#) (see below for definition), your best estimation of the answer to your research question. Then describe the reasoning that led you to your hypothesis, using what you know about the scientific concept as a basis for your reasoning.

Hypothesis:

A hypothesis is a scientist's best estimation, based on scientific knowledge and assumptions, of the results of an experiment. It usually describes the anticipated relationship among variables in an experiment. Since dependent variables "depend" on independent variables, there has to be a relationship between the two. The anticipated relationship between the dependent and independent variables is the result you expect when one variable reacts with another.

A hypothesis typically leads to the crucial questions that must be addressed in the lab report: did you find what you expected to find? why or why not? The point of an experiment is to test the hypothesis. Write or sketch your hypothesis, describing the relationship among the variables you listed .

Example:

What is your hypothesis for the answer to your research question?

I hypothesize that the countermovement jumps will be higher than jumps from the squat position. I further hypothesize that the faster the downward countermovement of the jump the higher the jump. The reasoning behind these hypotheses comes out of Newton's third law of motion. If for every action there is an equal and opposite reaction, then it is reasonable to expect that the more force that is exerted against the jumping surface the higher the jump. And the downward movement preceding the actual jump would apply more force against the jumping surface than simply jumping,

like a wound up spring, from a squat position.

It is also logical that more rapid countermovements will put more force on the jumping surface and thus will lead to higher jumps. Generally speaking, then, the greater the force a jumper can apply against the jumping surface, the greater the acceleration and velocity of the resulting jump, the more time the jumper is in the air, and, therefore, the higher the jump.

4. What variables can you use to test your hypothesis? A well-designed experiment needs to have variables. Look over your hypothesis, and identify the variables that you will be testing during your experiment: what you can measure or observe (dependent variables) and what you can manipulate in an experiment for the measurements or observations (independent variables). List your variables. Then describe, in words or in a sketch, the relationship among the variables as predicted by the hypothesis. (See below for definitions of underlined terms.)

Variables:

A variable is what is measured or manipulated in an experiment. Variables provide the means by which scientists structure their observations. Identifying the variables in an experiment provides a solid understanding of the experiment and what the key findings in the experiment are going to be.

To identify the variables, read the lab procedure described in the lab manual. Determine what you will be measuring and what you will be manipulating for each measurement. The value(s) you are manipulating is called the independent variable (see definition below) and the value(s) you are observing/recording is called the dependent variable (see definition below). Write down the dependent and independent variables. In more advanced labs, you may have multiple variables (see definition below), more than one independent and dependent variable.

Multiple Variables:

It is possible to have experiments in which you have multiple variables. There may be more than one dependent variable and/or independent variable. This is especially true if you are conducting an experiment with multiple stages or sets of procedures. In these experiments, there may be more than one set of measurements with different variables.

Example: You are interested in finding out which color, type, and smell of flowers are preferred by butterflies for pollination. You randomly choose an area you know to be inhabited by butterflies and note all the species of flowers in that area. You want to measure pollination of flowers by butterflies, so your dependent variable is pollination by butterflies. The independent variables are flower color, type, and smell. You will need to specify relationships for each of these independent variables with the dependent variable.

Dependent Variable:

A dependent variable is what you measure in the experiment and what is affected during the experiment. The dependent variable responds to the independent variable. It is called dependent because it "depends" on the independent variable. In a scientific experiment, you cannot have a dependent variable without an independent variable.

Example: You are interested in how stress affects heart rate in humans. Your independent variable would be the stress and the dependent variable would be the heart rate. You can directly manipulate stress levels in your human subjects and measure how those stress levels change heart rate.

Independent Variable:

An independent variable is the variable you have control over, what you can choose and manipulate. It is usually what you think will affect the dependent variable. In some cases, you may not be able to manipulate the independent variable. It may be something that is already there and is fixed, something you would like to evaluate with respect to how it affects something else, the dependent variable like color, kind, time.

Example: You are interested in how stress affects heart rate in humans. Your independent variable would be the stress and the dependent variable would be the heart rate. You can directly manipulate stress levels in your human subjects and measure how those stress levels change heart rate.

Example:

What variables can you use to test your hypothesis?

Because I have two hypotheses, I need two sets of independent and dependent variables. For the first hypothesis (that the countermovement jumps will be higher than squat jumps), my independent variable will be the two different approaches to the biomechanics of jumping, the countermovement jump and the squat jump. These are independent variables because I will be able to manipulate them in my experiment. My dependent variables, what I will be measuring in the experiment, will be the heights of jumps by the subjects in my experiment.

For my second hypothesis (that the faster the countermovement the higher the jump), my independent variable will be the different downward speeds my subjects will use as they jump. The dependent variables will be the different heights of these jumps by the subjects in this experiment.

5. What experiment(s) could you use to test your hypothesis? Referring to the list of variables, brainstorm some experiments you could do that would allow you to manipulate variables so that you can make the measurements or observations necessary for testing the hypothesis. Your experiment may require [control and treatment groups](#) (see below for definition). Choose the experiment most likely to yield the results you need to test your hypothesis. List the materials and outline the methods you will use for your experiment. (Remember that you have to work with the materials and lab instruments available to you.)

Control and Treatment Groups:

A control group is used as a baseline measure. The control group is identical to all other items or subjects that you are examining with the exception that it does not receive the treatment or the experimental manipulation that the treatment group receives. For example, when examining test tubes for catalytic reactions of enzymes when added to a specific substrate, the control test tube would be identical to all other test tubes with the exception of lacking the enzyme. The treatment group is the item or subject that is manipulated. In our example, all other test tubes containing enzyme would be part of the treatment group.

Example:

What experiment(s) could you use to test your hypothesis?

Experiment #1. I will use 6 players from my volleyball team. I will begin by training the players in the two approaches to jumping biomechanics, giving them opportunities to practice each approach. Then each player will make a series of five paired jumps related to the independent variable. Three players will do pairs consisting first of a squat jump and then a countermovement jump. The three other players will have the opposing pairing, first countermovement jump and then squat jump. (This is to be sure that fatigue doesn't affect the results.) The players will make their jumps in a standard set up used for jumping exercises: a suspended board with measurement lines marked on it that players will touch at the height of their jump. I will record the height of each of the jumps.

Materials needed: vertical jump measurement set-up

Experiment #2. I will use the same 6 players. I will ask each one to make five countermovement jumps, each jump in the series consisting of a downward thrust of a different speed, which I will measure according to the time it takes. I will train the players to jump to a number count from the moment they begin the downward movement to the point their feet leave the jumping surface. Half the players will start with a slow downward movement, the first to a count of 5, second 4, and so on to a quick count of 1. The other half will proceed from fast to slow. In order to make more accurate measurements of the speed of the countermovements, I will videotape the jumps and time each of them (from the beginning of the downward movement to the point the feet are off the surface) with a stopwatch while viewing the video later. I will record the height of each of the 5 jumps in the series.

Materials needed: vertical jump measurement set-up; camcorder; stopwatch; VCR.

References

Linthorne, Nick. "Standing Vertical Jump."

<http://www.brunel.ac.uk/~spstnpl/BiomechanicsAthletics/VirticalJumping.html> (3 January 2004).

Linthorne, Nicholas P. "Analysis of standing vertical jumps using a force platform."

American Journal of Physics 69 (2001): 1198-1204.



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NC STATE UNIVERSITY

Designing Your Own Lab Experiments Handout

PreLab: questions to answer before doing the lab

Name: _____

Date: _____

Lab Section: _____

Lab Title: _____

Note: This is the handout version, which only contains the PreLab questions in "Designing Your Own Lab Experiments." For more help or additional information, you'll need to go to the on-line version of PreLab at <http://labwrite.ncsu.edu> where you can view additional materials on-line or obtain a full printable version under PreLab- "Designing Your Own Lab Experiments" SelfGuide.

1. What is the problem? Describe the problem in your own words. Be sure that your description includes known factors (information about the problem given to you in the lab in a problem statement, for example) and unknowns (what you need to find out in order to solve the problem). Then restate the problem in the form of a question or questions that will guide your research.

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Descriptive Labs SelfGuide

Printable Version

InLab: the lab procedure

1. Setting up the lab:

Take notes as you set up your experiment and calibrate instruments to help you document your experimental protocol so that you may use it later when writing the Methods section of your lab report.

On a sheet of paper or in your lab manual or in a formal [lab notebook](#), list the lab materials you'll be using and describe the set-up for this experiment. Take notes about potential [sources of uncertainty](#) so that you may refer to them when you are writing the Discussion section of your lab report. You may want to or may be required to draw and label the instrument(s) you'll be using.

(See below for definitions of underlined words.)

(Refer to the web version of this document for example lab notebook pages.)

Lab notebook:

Keeping accurate lab notebooks is very important for professional scientists and engineers. Their lab notebooks are permanent legal records of all work conducted in the laboratory. Because of their importance, professional lab notebooks should be:

- Logs or journals of all the information collected during lab, including procedures and sketches of instruments or tools.
- Written in ink with corrections initialed and noted.
- Labeled with page numbers, time, date, and titles for all procedures, tables, charts, graphs, etc.

Sources of Uncertainty:

In science, a source of uncertainty is anything that occurs in the laboratory that could lead to uncertainty in your results. Sources of uncertainty can occur at any point in the lab, from setting up the lab to analyzing data, and they can vary from lab to lab. This is why it is so important to keep detailed notes of everything you do in the lab procedure and any problems you encounter. Try to be especially aware of any problems in setting up the lab, calibrating instruments, and taking measurements as well as problems with the materials you are using.

For advanced labs, you may want to classify the kinds of uncertainty you have identified. Sources of uncertainty can be classified as random-those that cannot be predicted-or as systematic-those that are related to personal uncertainty, procedural uncertainty, or instrumental uncertainty.

2. Preparing a table or spreadsheet for recording your data:

Using the information you have gathered about the data you will be collecting and list of variables from your PreLab as a guide, create a **raw data table** or **set up a spreadsheet** for entering data from your experiment. For help in determining which you should create now, a table or a spreadsheet, [see below](#) . For general information on tables, go to **Designing Tables**. (refer to the

web version of this document to access these resources)

Creating a Table or a Spreadsheet:

A table provides a very convenient tool for organizing the data you collect in your lab. You can quickly draw a table on a sheet of paper, you can make one with a word processing program, or you can generate one with spreadsheet software. Using a hand-drawn table in the lab also allows you the flexibility of entering the data into a spreadsheet at a later time. The chief advantage to entering data in a spreadsheet is that you can easily convert it not only into a table but also into all sorts of graphs.

Use this guide to figure out whether or not you should use a table or a spreadsheet for recording your data in the lab:

- If you do not have access to a computer with spreadsheet software in your lab, then you should create a table. You can use the data in the table to generate a spreadsheet later, if necessary.
- If you know you will need to create graphs for your data and have access to spreadsheet software in the lab, then use the spreadsheet.
- If you are not sure what form, table or graph, you will be using to report your findings and it is convenient to use a spreadsheet, then use a spreadsheet.
- If creating a spreadsheet in the lab will take too much lab time, then use a table and create the spreadsheet later.

3. Conducting the experiment:

Conduct your experiment as set up in the PreLab and record your data in a table or spreadsheet (see question 2 above). Take detailed notes on your experimental procedures. These notes may be all you have later on when you write your lab report. It's also important to note any problems you have with the experiment; these notes could be useful when writing the Discussion. Describe in writing or sketch out on a sheet of paper your observations as you collect data during the experiment (observations are potentially significant things that are not reflected in the measurements: color, smell, interesting reactions, unexpected behaviors, etc.)

As you record your data, take note of any trends emerging in the data. You should be asking yourself various questions: What are the [relationships among the variables](#)? Do the data behave in the way that you had anticipated? If not, why not? You may need to consider [sources of uncertainty](#) once again. Sources of uncertainty may affect the [accuracy and precision](#) of your experimental data. (See below for definitions of underlined words.)

Note: If the results of your experiment do not seem to lead you to an answer to your research question, you may need to rethink the design of your experiment, which could mean revising the experiment, revising the variables, revising the hypothesis, or even revising the research question. A good scientist must be flexible in designing and conducting experiments. Remember that the most important part of an experiment is that it is clearly designed so that it may be repeated by others seeking to reach the same conclusions. Whether you are right or wrong with respect to your hypothesis is not as important as a well-designed experiment.

Relationships Among the Variables:

Since dependent variables "depend" on independent variables, there has to be a relationship between the two. The relationships between the dependent and independent variables are what is described in the hypothesis. So it's important to determine what those relationships are in order to see whether or not the hypothesis has been supported.

Sources of Uncertainty:

In science, a source of uncertainty is anything that occurs in the laboratory that could lead to uncertainty in your results. Sources of uncertainty can occur at any point in the lab, from setting up the lab to analyzing data, and they can vary from lab to lab. This is why it is so important to keep detailed notes of everything you do in the lab procedure and any problems you encounter. Try to be especially aware of any problems in setting up the lab, calibrating instruments, and taking measurements as well as problems with the materials you are using.

For advanced labs, you may want to classify the kinds of uncertainty you have identified. Sources of uncertainty can be classified as random-those that cannot be predicted-or as systematic-those that are related to personal uncertainty, procedural uncertainty, or instrumental uncertainty.

Accuracy and Precision:

Accuracy refers to the closeness of a measured value to a standard or known value. For example, if in lab you obtain a weight measurement of 3.2 kg for a given substance, but the actual or known weight is 10 kg, then your measurement is not accurate. In this case, your measurement is not close to the known value.

Precision refers to the closeness of two or more measurements to each other. Using the example above, if you weigh a given substance five times, and get 3.2 kg each time, then your measurement is very precise. Precision is independent of accuracy. You can be very precise but inaccurate, as described above. You can also be accurate but imprecise.

For example, if on average, your measurements for a given substance are close to the known value, but the measurements are far from each other, then you have accuracy without precision.

A good analogy for understanding accuracy and precision is to imagine a basketball player shooting baskets. If the player shoots with accuracy, his aim will always take the ball close to or into the basket. If the player shoots with precision, his aim will always take the ball to the same location which may or may not be close to the basket. A good player will be both accurate and precise by shooting the ball the same way each time and each time making it in the basket.

4. Visualizing the data:

Now that you have entered your data in a table or spreadsheet, you are ready to represent the data in the appropriate visual format for your lab report. Representing your data in a visual format will allow you to identify trends and relationships among variables more easily. Follow these steps:

- Establish what types of data you have, **quantitative or qualitative** (refer to the Resources page in the web version of this document; once there, choose "Data Types").
- Determine if the data should be represented as a **table or a graph** (refer to the Resources page in the web version of this document; once there, choose "Tables vs. Graphs").
- If you decide to use a graph to represent your data, determine which **type of graph** is one that best represents your data (refer to the Resources page in the web version of this document; once there, choose "Graph Types").
- If a table is the best format for your data, then modify the table you used to collect your data so that it is labeled and organized properly (refer to the Resources page in the web version of this document; once there, choose "Designing Tables").
- If you need help creating a spreadsheet to make a table or graph, refer to the

Resources page in the web version of this document. Once there, choose "Excel Tutorial".

- Remember that the purpose of your table or graph is to summarize your findings for yourself and for others and to reveal trends in your data.

5. Using your data to solve your research problem:

Review all your data--tables, graphs, and drawings--to establish whether or not or to what degree the data support your hypothesis. Next, use what you have learned from comparing data to the hypothesis to answer your research question. State the answer as best you can in a sentence or two. Then return to the original problem you were given to solve, both the knowns and the unknowns that you defined in Question 1 of the PreLab. Does the answer to your research question resolve the unknowns and allow you to solve the problem? If so, write the solution. If your answer still does not provide a satisfactory resolution to your research question and the original problem, you may need to explore alternatives: a different experiment, a different hypothesis, a different research question.



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NC STATE UNIVERSITY

Designing Your Own Lab Experiments Handout

InLab: the lab procedure

Name: _____

Date: _____

Lab Section: _____

Lab Title: _____

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2. Preparing a table or spreadsheet for recording your data:

Using the information you have gathered about the data you will be collecting and list of variables from your PreLab as a guide, create a raw data table or set up a spreadsheet for entering data from your experiment.

3. Conducting the experiment:

Conduct your experiment as set up in the PreLab and record your data in a table or spreadsheet (see question 2 above). Take detailed notes on your experimental procedures. It's also important to note any problems you have with the experiment; these notes could be useful when writing the Discussion. Describe in writing or sketch out on a sheet of paper your observations as you collect data during the experiment (observations are potentially significant things that are not reflected in the measurements: color, smell, interesting reactions, unexpected behaviors, etc.)

As you record your data, take note of any trends emerging in the data. You should be asking yourself various questions: What are the relationships among the variables? Do the data behave in the way that you had anticipated? If not, why not? You may need to consider sources of uncertainty once again. Sources of uncertainty may affect the accuracy and precision of your experimental data.

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- If you need help creating a spreadsheet to make a table or graph, refer to the Resources page in the web version of this document. Once there, choose "Excel Tutorial."
- Remember that the purpose of your table or graph is to summarize your findings for yourself and for others and to reveal trends in your data.

5. Using your data to solve your research problem:

Review all your data--tables, graphs, and drawings--to establish whether or not or to what degree the data support your hypothesis. Next, use what you have learned from comparing data to the hypothesis to answer your research question. State the answer as best you can in a sentence or two. Then return to the original problem you were given to solve, both the knowns and the unknowns that you defined in Question 1 of the PreLab. Does the answer to your research question resolve the unknowns and allow you to solve the problem? If so, write the solution. If your answer still does not provide a satisfactory resolution to your research question and the original problem, you may need to explore alternatives: a different experiment, a different hypothesis, a different research question.



PostLab: writing your lab report

The following pages include the PostLab guide for writing your lab report. A good strategy is to open a word processing file and write the report following the directions step by step. Follow the LabWrite process, beginning with writing Methods and finishing with writing the title. Then when you've finished, you can rearrange the sections of your report in the proper order for turning it in.

Descriptive Labs SelfGuide

Printable Version

PostLab: writing your lab report

SECTION ONE : Methods

Describing the lab procedure

Using the notes you took while performing your experiment(s) and any other appropriate sources, describe in paragraph form the experimental procedures you followed. Be sure to include enough detail about the materials and methods you used so that someone else could repeat your experiment as you performed it.

More Help:

- In writing the Methods, you need to rely primarily on the notes you took as you were doing the experiment. Think of your audience as someone who does not know what experiment you performed. Include enough details about both the materials you used and what you did so that the audience has a clear picture of the experiment.
- Write the procedure in paragraph form. For relatively simple labs, one paragraph will do; more complex labs will take multiple paragraphs. Keep the paragraphs relatively short because it's hard for readers to process detailed information like this without sufficient breaks.
- Avoid putting any results of the lab in the Methods. Just describe what you did, not what you found.
- Use the proper past tense and passive voice. Methods are usually written in past tense because you are describing what you have already done. They are also typically written in passive voice ("Two ml. *were pipetted* into a test tube"). However, your lab instructor may permit you to use active voice, which uses first person, "I" or "we" ("We *pipetted* 2 ml. of the solution into the test tube").

More Helpful Hints:

- To make your description of the experimental procedure clear, use appropriate transitional or "sign post" words that indicate a sequence and help the reader follow the sequence: step 1, step 2, step 3; first, then, finally; first, second, third; after, next, later, following; etc.
- Include the methods you used for both gathering data and analyzing the data.
- If your lab is complicated, perhaps consisting of more than one experimental procedure, then consider dividing your Methods into sections with subheadings.
- If you used what is considered a standard procedure (one that competent scientists in the field are likely to be familiar with) then there is no need to describe it in detail. Simply state that you used that procedure, being sure to give its common name. (If you are not sure about what standard procedures are in your field, ask your lab instructor.)
- When describing an apparatus or instrument, it may be better to include a sketch of it rather than to try to describe it fully in words. This is especially useful in cases where the apparatus is complex or designed by you. All you need is a couple of sentences that give a general sense of the apparatus, and

then refer the reader to the figure that contains the sketch, the same way you would refer the reader to tables or graphs.

SECTION TWO : Results

Making sense of your data for yourself and others

Step 1: If you haven't already done so, put your lab data in visual form by creating appropriate tables, graphs, and other figures. Representing your data in a visual format will allow you to identify trends and relationships among variables more easily.

More Help:

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- If a table is the best format for your data, then modify the table you used to collect your data so that it is labeled and organized properly (refer to the Resources page in the web version of this document, once there, choose "Designing Tables").
- If you need help creating a spreadsheet to make a table or graph, refer to the Resources page in the web version of this document. Once there, choose "Excel Tutorial."

Step 2: Once you have generated visual representations of your data, decide the order in which your tables, graphs, or other figures should be presented in the Results section.

More Help:

If you have multiple data sets, you can arrange your visuals according to one of these methods of ordering:

- chronological order: if the lab consists of more than one procedure, you can present the results in the order in which you did the procedures, especially if that order provides a useful way of leading the reader through the results.
- order of importance: arrange the visuals by putting the one that is the most important first and then the others in descending order of importance.
- order of generality: sometimes it is better to start with the most general representation of the data and then place the more specific ones after that, especially if the specific ones serve to support the broad representation or add more details to it.

Step 3: Review all the data from your experiment. In a sentence or two summarize the overall results of this lab. This is the opening sentence(s) of the Results section.

More Help:

- In your summary, be sure to focus only on the findings, the data from the experiment. Don't address the hypothesis.
- Review the data in your visuals (tables and graphs and other figures). If you have trouble shaping a one- or two- sentence summary, look for a unifying feature among the data sets. This is likely to be the dependent variable. The sentence will be a general statement that summarizes your findings about that variable or related variables.
- You can start the sentence in several ways: "The results of the lab show that ..."; "The data from the experiments demonstrate that..."; "The independent variable X increased as Y and Z were...."

Step 4: In separate paragraphs summarize the finding in each of your visuals--tables, graphs, or other figures. First state the overall relationship or interaction among variables that each visual represents. Then include any specific details from the visual that are important for understanding the results. Refer to your tables, graphs, or other figures as figure or table 1, 2, 3, etc.

More Help:

- Describe each visual in a separate paragraph. Each paragraph has two parts:
 1. The first sentence gives the **general finding** (see definition below) for the visual, what it indicates overall, and
 2. The following sentence(s) provides key details from the visual that are important to understanding the experiment (don't include all the details).
- Refer to your visual(s) in the written part of your Results in one of two ways:
 1. Refer to your visual(s) at the beginning of your findings, for example, "Table 1 shows that the reaction times decreased as the strength of the solution increased." "Figure 3 demonstrates that the mortality rate among riparian mammals adhered to approximately seven-year cycles." (It is also possible to use verbs such as "*lists*," "*displays*," "*describes*," etc.)
 2. Refer to your visual(s) in parentheses at the end of the of your findings. For example, "The reaction times decreased as the strength of the solution increased (Table 1)." "The mortality rate among riparian mammals adhered to approximately seven-year cycles (see Figure 3)." (Ask your teacher which format to use for parenthetical documentation.)

General Finding:

You can determine the general finding for each visual in one of two different ways:

as a summary of all the information in the visual **OR** as a statement that focuses on the most important point that is made in the visual (important, that is, in terms of the hypothesis).

- Refer to your visual(s) in the written part of your Results in one of two ways:
 1. Refer to your visual(s) at the beginning of your findings, for example, "Table 1 shows that the reaction times decreased as the strength of the solution increased." "Figure 3 demonstrates that the mortality rate among riparian mammals adhered to approximately seven-year cycles." (It is also possible to use verbs such as "*lists*," "*displays*," "*describes*," etc.)
 2. Refer to your visual(s) in parentheses at the end of the of your findings. For example, "The reaction times decreased as the strength of the solution increased (Table 1)." "The mortality rate among riparian mammals adhered to approximately seven-year cycles (see Figure 3)." (Ask your teacher which format to use for parenthetical documentation.)

Step 5: Complete the Results by placing all the elements you've written in the proper order: (1) the sentence summarizing the overall data for the lab; (2) the paragraphs of word descriptions for each visual arranged in the order the visuals are presented. Remember that the Results only reports and describes what you observed and collected during your lab. The Results does not explain, discuss, or draw conclusions.

The Results looks like this:

- Summary of overall findings of lab
- Paragraph related to visual 1
 1. Sentence of overall finding from visual 1
 2. Sentence(s) with key details from the visual 1
- Paragraph related to visual 2
 1. Sentence of overall finding from visual 2
 2. Sentence(s) with key details from the visual 2
- Paragraph related to visual 3
 1. Sentence of overall finding from visual 3
 2. Sentence(s) with key details from visual 3, etc.

SECTION THREE : Introduction

Establishing a context for the lab

Step 1: (Use your response to PreLab question 1 for this step.) Briefly describe the research problem you were given to solve. Define the problem by giving the knowns and the unknowns. Then state the research question that you used to guide the research to solve your problem. This will be the first paragraph or so of your Introduction.

More Help:

- If you are having trouble writing a good opening sentence for the lab report, you can say something like: "The problem for this lab was X..." "The problem we were asked to solve was X..."
- As you are defining the problems, don't just list the knowns and unknowns. Describe them in paragraph form.
- You can give your research question in the form of a question or as a statement, such as "To solve this problem, it is necessary to find Y..."
- Be sure to make the connection between the unknowns and the research question, to show how answering the question will lead to the solution to the problem.

Step 2: (Use your response to PreLab questions 2 and 3 for this step.) In the next paragraph or two, state the scientific concept that this problem relates to. Then describe what you know about the scientific concept that is relevant to understanding and solving the problem. Note any citations you use here for References section.

More Help:

- If you are having trouble starting this paragraph, here are some suggestions: "The problem for this lab is based on Z..."; "This laboratory is about X..." ; "This lab is designed to help students learn about, observe, or investigate, X..." Or begin with a definition of the scientific concept: "X is a theory that...."
- Once you have your opening sentence, you are ready to complete the opening paragraph by telling what you know about the scientific concept. The point is to show your lab instructor that you have a good grasp of the scientific concept. Revise your response to the PreLab question by:
 - Focusing it so that it contains information about the concept that is most clearly related to the lab problem (not everything there is to know about the concept).
 - Incorporating additional relevant information about the concept you may have learned since doing the PreLab.
 - Changing it so that the scientific concept is appropriate to the lab (this would apply if all or parts of what you wrote about the scientific concept in the Pre-Lab are wrong for this lab).
- If you have a lot to say about the scientific concept, use more than one paragraph.
- This part of the Introduction is typically written in present tense.

For more advanced labs:

If you are writing a lab report that is intended to be more like a full scientific paper, you may need to do more research using the Internet and library. With your teacher's guidance, you should search the recent scientific literature to find other research in this area of study. Summarize that research in a paragraph or so, stating what the general findings have been and using those findings to describe the current knowledge in the area (such a "review of the literature" is typical of scientific journal articles). This summary should come after your initial sentence about the scientific concept. For help with citing references, go to Citations and References in the Resources page.

Step 3: (Use your response to PreLab questions 3-5 for this step.) In a paragraph or two, present the hypothesis that emerged out of the research question. Then explain the reasoning you used, based on what you have said about the scientific concept, to arrive at the hypothesis. Finally, in a sentence or two, briefly describe the experimental procedures you used to test your hypothesis.

More Help:

- Revise your original hypothesis from the PreLab so that it is clearly stated: "The hypothesis for this lab was..."; "My hypothesis was..."; "We predicted that..."; "I hypothesized that..."
- As you are explaining the reasoning you used to come to your hypothesis, be sure to make a direct connection between the hypothesis and the scientific concept of the lab. You can also use basic scientific logic that is not specifically linked to the scientific concept.
- One way to make your explanation clearer is to use words that show causal links: *because, since, due to the fact that, as a result, therefore, consequently,* etc. For example, Since X happens in order to maximize energy, we hypothesized that . . .
- If your explanation is relatively long, use more than one paragraph.

SECTION FOUR : Discussion

Interpreting the results of the lab

Step 1: Write a sentence or two stating whether or not the results from the lab procedures fully support your hypothesis, do not support the hypothesis, or support the hypothesis but with certain exceptions.

More Help:

- Go back to the first part of your Introduction. Then review your findings, the data from the experiment. Make a judgment about whether or not the hypothesis has been supported. It is at this point that you, as a scientist, must be as unbiased and objective as possible.
- Write a sentence stating your judgment. There are three possible judgments you can make:
 1. the data support the hypothesis;
 2. the data do not support the hypothesis; or
 3. the data generally support the hypothesis but with certain exceptions (tell what those exceptions are).

Example: "The hypothesis that X solution would increase in viscosity when solutions Y and Z were added was supported by the data."

Step 2: In a paragraph, identify specific data from your lab that led you to either support or reject your hypothesis. Refer to the visual representations of your data as evidence to back up your judgment about the hypothesis.

More Help:

- Return to the Results to identify the particular data that led you to your judgment about the hypothesis.
- Write a paragraph (or 2 if necessary) in which you present the relevant pieces of data from the lab and show how they relate to the hypothesis.
- Refer to data from specific visuals appropriately: Table 1, Figure 2, etc.

Step 3: In a paragraph or two, use your understanding of the scientific concept of this lab to explain why the results did or did not support your hypothesis. If the hypothesis from the Introduction was not fully supported, show how your understanding of the scientific concept has changed. Note any citations you use here for including in the Reference section of your report.

More Help:

In Step 2 you pointed to data that led you to your judgment about your hypothesis. Now you use your understanding of the scientific concept of the lab to explain your judgment. Whatever the relationship between the hypothesis and the results, you must provide a logical, scientific basis for it.

- Return to the scientific reasoning you used to generate your hypothesis (Step 2 of the Introduction). Use it and your understanding of the scientific concept of the lab as starting points for your explanation. Your explanation is likely to follow one of four scenarios. Choose the one that best fits your report:
 - If the results fully support your hypothesis and your reasoning in the Introduction was basically sound, then elaborate on your reasoning by showing how the science behind the experiment provides an explanation for the results.
 - If the results fully support your hypothesis but your reasoning in Introduction was not completely sound, then explain why the initial reasoning was not correct and provide a better reasoning.
 - If the results generally support the hypothesis but in a limited way, then describe those limitations (if you have not already done so) and use your reasoning as a basis for discussing why those limitations exist.
 - If the results do not support your hypothesis, then explain why not; consider (1) problems with your understanding of the lab's scientific concept; (2) problems with your reasoning, and/or (3) problems with the laboratory procedure itself (if there are problems of reliability with the lab data or if you made any changes in the lab procedure, discuss these in detail, showing specifically how they could have affected the results and how the uncertainties could have been eliminated).

Step 4: In a paragraph or two, restate the research question and present the answer your experiment has suggested for that question. Show how the experiment has helped you to solve for the unknowns. Then restate the problem that your research was designed to solve and discuss the solution to the problem suggested by the answer to the research question.

More Help:

At this point in the lab report you return to where you started in the Introduction, the problem. The goal of the lab was to answer the research question in order to solve the problem. Now that you have presented your data and made a judgment about your hypothesis, you are ready to come full circle back to the problem.

- Go back to the research question you posed in the Introduction. The experiment you performed was designed to answer that question. If you are having trouble starting this paragraph, here are some suggestions: "The research question for this experiment was...."; "The experiment described in this report was designed to answer the question,..."; "The research reported here addressed the issue of...".
- The research question probably grew out of the unknowns in the problem. Answer the question in such a way that you show a direct link between the answer and the unknowns.
- The solution to the problem is most likely going to center on the identification of the unknowns. State the solution to the problem and show how the solution to the problem came out of the identification of the unknowns.
- A good discussion is going to enable the reader to draw a clear line from the experimental data through the hypothesis and the answer to the research question to the solution to the problem.

Step 5: Discuss other items as appropriate, such as (1) any problems that occurred or [sources of uncertainty](#) (see below for definition) in your lab procedure that may account for any unexpected results; (2) how your solution to the problem compared with the solutions of other students in the lab and an explanation for any differences; (3) suggestions for improving the lab.

More Help:

- In science, a source of uncertainty is anything that occurs in the laboratory that could lead to uncertainty in your results. Sources of uncertainty can occur at any point in the lab, from setting up the lab to analyzing data, and they can vary from lab to lab. Return to the notes you took during the lab procedure. Look for possible sources of uncertainty in setting up the lab, calibrating instruments, and taking measurements as well as problems with the materials you are using.
- In scientific articles, the Discussion is where scientists typically compare their results to those from other similar scientific experiments. You can do something similar in your lab report. If you have compared your results with others in your lab, describe what you found and comment on any differences in the solutions to the problem: what were the differences, why there were differences, and what are the implications of the differences for the problem? Be sure to check with the lab instructor beforehand to see if it is permissible to compare results.

For more advanced labs:

- It may be useful to classify the kinds of uncertainty you have identified. Sources of uncertainty can be classified as random--those that cannot be predicted--or as systematic--those that are related to personal uncertainty, procedural uncertainty, or instrumental uncertainty.

Sources of Uncertainty:

In science, a source of uncertainty is anything that occurs in the laboratory that could lead to uncertainty in your results. Sources of uncertainty can occur at any point in the lab, from setting up the lab to analyzing data, and they can vary from lab to lab. This is why it is so important to keep detailed notes of everything you do in the lab procedure and any problems you encounter. Try to be especially aware of any problems in setting up the lab, calibrating instruments, and taking measurements as well as problems with the materials you are using.

For advanced labs, you may want to classify the kinds of uncertainty you have identified. Sources of uncertainty can be classified as random--those that cannot be predicted--or as systematic--those that are related to personal uncertainty, procedural uncertainty, or instrumental uncertainty.

SECTION FIVE : Conclusion

Focusing on what you learned by doing the lab

Step 1: Write a paragraph summarizing what you have learned about the scientific concept of the lab from doing the lab. Back up your statement with details from your lab experience.

More Help:

- Return to the scientific concept you established in the Introduction. But instead of describing what you know about the scientific concept in the Conclusion, describe what you learned about the concept from doing the lab. For example:
 - How did solving the problem help you to learn about the concept?
 - How has your understanding of the concept improved or otherwise changed from

- doing the lab?
- What specific aspects of the procedure or data contributed to your learning?
- What difficulties did you have with the concept before doing the lab and how were those difficulties alleviated by doing the lab?
- How might what you have learned in the lab be applicable in the future?
- Be direct in your statement of what you have learned. Don't be afraid to start out saying, "In this lab, I learned that" This sort of clarity will be appreciated by the reader. Elaborate on your statement with additional details about what you have learned.

Step 2: If there is anything else you have learned about from doing the lab, such as how to solve this particular problem, how to design an experiment, the kinds of the lab procedures or kinds of analyses you used, describe it in a paragraph or 2.

More Help:

- There may be more that you have learned about from the lab experience than the scientific concept of the lab. If so, write a paragraph describing it. For example:
 - What did you learn about experimental design, how to design an experiment?
 - Was there anything in the experimental procedure that you found particularly interesting to learn how to do?
 - Did you apply a procedure for analyzing data that was useful to learn about?
 - Did you learn anything about using a spreadsheet or graphing or creating other visuals?
 - Did you learn anything about writing or about science from writing the report?

SECTION SIX : Abstract

Summarizing the lab report

Summarize each major section of the lab report--Introduction, Methods, Results, Discussion, and Conclusion--in 1 sentence each (two if a section is complex). Then string the summaries together in a block paragraph in the order the sections come in the final report.

More Help:

You can think of the Abstract as a miniature version of the whole lab report. Read each section of the report and boil it down to a sentence. This means that you need to determine the most important information in each section.

- Here are some suggestions for what to include in each sentence of the Abstract:
 - Introduction: research problem of the lab; hypothesis
 - Methods: a quick description of the procedure
 - Results: statement of the overall findings
 - Discussion: judgment about hypothesis; solution for problem
 - Conclusion: what you learned from doing the lab
- Put all these sentences together into one paragraph with the heading "Abstract."

SECTION SEVEN : Title

Capturing the essence of the report

Write a title that captures what is important about the lab, including the scientific concept the lab is about and variables involved, the procedure, or anything else that is important to understanding what this report is about.

More Help:

You write the title after you have written the other parts of the report, because the title reduces the report down to its essence, and it's not until you finish writing the report that you are able to identify what that essence is. A good title very efficiently tells the reader what the report is about.

Hints:

- If you are having trouble writing a title, try this approach. List the keywords related to the report: the scientific concept of the lab, the kind of procedure you used, names of key materials, what you experimented on, etc. Then write a title that describes the lab using the most important of these keywords.
- A title should use the fewest possible words to adequately describe the content of the report.
- A title should be as specific as possible. Specify the primary focus of the experiment and procedures used, including the scientific names of chemicals, animals, etc.
- Do not write the title as a complete sentence, with a subject and a verb. Titles are labels, not sentences.
- Do not use catchy titles. This is not an English paper or an editorial.
- Find the right balance for the length of the title: not so short that it doesn't communicate what the report is about but not so long that it rambles on for more than a line.

SECTION EIGHT : References

Acknowledging sources of information

If it is appropriate for your lab report, put a References section at the end. List all the sources you referred to in writing the report, such as the lab manual, a textbook, a course packet, or scientific articles. Be sure to use the proper form of documentation for the scientific field you are working in (ask your lab instructor if you are not sure). See [Citations and References](#) in the web version of this document.

More Help:

- Different scientific fields use somewhat different styles for documenting sources in the References. For example, in chemistry you would follow the American Chemical Society (ACS) style. In biology, it would be the Council of Biological Editors (CBE) style. Check to see which style is appropriate for your class.
- You can find information about various documentation styles at [Citations and References](#) in the web version of this document.

Designing Experiments

LabChecklist : SelfGuide

The Title of my Lab Report...

- describes the specific content of the lab concisely but with enough detail to get the main ideas across to the reader.

The Abstract of my Lab Report...

- summarizes the gist of each section of the report in a sentence (or two for an especially complex section).
- arranges the sentences in the order the sections are presented in the report, Introduction to Conclusion.
- stays within the maximum words allowed (usually 100-200 words, but if there is a different word limit for your class, be sure you are within it).

The Introduction in my Lab Report...

- defines the research problem by briefly describing it and stating the knowns and unknowns (what the problem gives you and what you need to find in order to solve the problem) and then gives the guiding research question (typically one paragraph).
- states in a sentence or two the scientific concept the lab is about and then describes what I know about that concept that is relevant to the lab (typically one or two paragraphs).
- Establishes the hypothesis that comes out of the research question, explains the reasoning (based on the scientific concept and logic) I used to arrive at the hypothesis, and finally briefly summarizes the experimental procedures used to test the hypothesis (typically one or two paragraphs).

The Methods in my Lab Report...

- provides a concise, easy-to-follow description of the specific procedures followed in the lab.
- gives enough detail of both the materials and the procedure used so that the experiment could be repeated just as I did it.

The Results in my Lab Report...

- begins with a sentence or two describing the overall findings of the lab.

contains visuals (tables or graphs or other figures) that are appropriate to the data and are arranged in an order that best tells the "story" of the data.

consists of a paragraph for each visual and structures each paragraph by (1) summarizing in a sentence or two the overall trend shown in that visual and then (2) supporting the summary by including any specific details from the visual that are important for understanding the results.

clearly refers to the appropriate visuals in the paragraphs (Table 1, Figure 2, etc.).

reports the data from the experiment only, successfully avoiding any explanations or conclusions about the data.

The Discussion in my Lab Report...

begins with a statement of whether or not the overall results support, do not support, or support to some extent my original hypothesis (from the Introduction).

points to specific data from the findings as evidence for deciding whether or not the hypothesis is supported

uses what I have learned about the scientific concept of the lab to explain in a convincing way why or why not the data support my hypothesis.

restates the research question, presents the answer to the question as suggested by the experiment, and then shows how the experiment solved the unknowns (which led to the answer of the research question).

restates the research problem the experiment was supposed to solve and gives the solution to the problem as suggested by the answer to the research question.

addresses other issues that may be appropriate, such as (1) any problems that occurred or sources of error in the lab procedure; (2) how my solution to the problem compared to the solutions of other students and explains any differences; (3) suggestions for improving the lab.

The Conclusion of my lab report...

directly states what I have learned about the scientific concept of the lab from doing the experimental procedure.

gives enough details of what I have learned to be convincing.

describes anything else I may have learned from doing the lab and writing the report (how to solve similar problems, how to design an experiment, some aspect of the lab procedure or methods of analyzing data, etc.).

The References for my lab report...

includes all the sources I have used in writing my lab report, such as

the lab manual, the textbook, and any reference books or articles I cited.

- uses the appropriate documentation style for citations and references (CBE, ACS, etc.)

Overall issues: My lab report...

- uses the correct format (titles, captions, etc.) for the tables, graphs, and drawings
- is written in a scientific style (tone should be objective; sentences should be clear and to the point).
- is clear of spelling errors (use the spell check on your computer).
- includes all the necessary headings (each section of the report should have a heading).



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NC STATE UNIVERSITY

Descriptive Labs SelfGuide

Printable Version

LabCheck: *Evaluation Guide*

Writer: _____

	F	D	C	B	A
<i>Title</i>					
• describes lab content concisely, adequately, appropriately					
<i>Abstract</i>					
• conveys a sense of the full report concisely and effectively					
<i>Introduction</i>					
• effectively defines the research problem and states the research question					
• successfully establishes the scientific concept of the lab					
• states hypothesis and provides logical reasoning for it					
<i>Methods</i>					
• gives enough details to allow for replication of procedure					
<i>Results</i>					
• opens with effective statement of overall findings					
• presents visuals clearly and accurately					
• presents verbal findings clearly and with sufficient support					
• successfully integrates verbal and visual representations					
<i>Discussion</i>					
• opens with effective statement of support of hypothesis					
• backs up statement with reference to appropriate findings					
• provides sufficient and logical explanation for the statement					
• gives answer to the research question and solution for unknowns					
• effectively links answer of research question to solution of problem					
• sufficiently addresses other issues pertinent to lab					
<i>Conclusion</i>					
• convincingly describes what has been learned in the lab					
<i>References</i>					
• all appropriate sources in the report are listed					
• citations and references adhere to proper format					
<i>Presentation</i>					
• format of tables and figures is correct					
• report is written in scientific style: clear and to the point					
• grammar and spelling are correct					
<i>Overall Aims of the Report: The student...</i>					
• has successfully learned what the lab is designed to teach					
• demonstrates clear and thoughtful scientific inquiry					
• accurately measures and analyzes data for lab findings					

LabWrite Resources

Graphing Resources

Excel Tutorial

A step-by-step tutorial on how to use Excel. It covers both basic techniques (entering raw data, formula entry, cell displays, basic graphing) and advanced techniques (such as importing raw data, creating various kinds of graphs, culling data, formatting graphs, and using descriptive statistics in graphs--error bars).

Data Types

A flow chart to use for help when trying to categorize the types of data collected during the lab.

Tables vs. Graphs

A guide with helpful hints on how to decide which format best represents the data collected in lab.

Designing Tables

General information on creating tables to represent data collected in lab.

Graph Types

A flow chart to use when trying to decide which type of graph best represents the type of data collected in lab.

Bar Graphs

Use this guide for a description of the different types of bar graphs followed with examples that illustrate when to use each one.

Histograms

Use this guide for a description of the different types of histograms followed with examples that illustrate when to use each one.

Line Graphs

Use this guide for a description of the different types of line graphs followed with examples that

illustrate when to use each one.

Scatter Plots

Use this guide for a description of the different types of scatter plots followed with examples that illustrate when to use each one.

Revising Your Visuals

A useful guide that provides helpful hints on how to refine and modify key elements of visuals to prepare them for final presentation.

Error Bars

Provides information on summarizing data with mean values and representing experimental uncertainty with error bars.

Representing Significant Digits

This page will give you some guidance on how to report your experimental results with the appropriate number of significant digits.

Writing Resources

Quick Guide to PostLab Stages

An abbreviated version of the Post-Lab stages to be used as a quick reference guide by those already familiar with Post-Lab.

LabChecklists

A checklist of the elements that need to be in an effective lab report is available for any type of lab you may have completed--standard, descriptive, or designed by you. The LabChecklist follows the guidelines presented in PostLab and is designed for use prior to turning in the lab report for a grade. Use this to double-check the lab report in order to improve the chances of getting a better grade.

Help Improving Your Lab Report Grade

Helpful hints on how to improve each component of the lab report for any type of lab you may have completed--standard, descriptive, or designed by you. Use this in conjunction with the LabCheck Evaluation Guides available for each type of lab for help in interpreting and improving lab report grades. Before using this resource, make sure you are familiar with PostLab.

LabCheck Evaluation Guides

A LabWrite Evaluation Guide is available for any type of lab you may have completed--standard, descriptive, or designed by you. The Evaluation Guide lists criteria that instructors will be using to grade your lab reports. Links to Help Improving Your Lab Report Grade are available within each section of the guide. Use this guide to become familiar with the LabWrite grading criteria before turning in your lab report and to help you interpret your lab report grade.

after you get it back.

Online Writing Handbook

Web sites to help you with questions about grammar, style, punctuation, mechanics, using the internet, search engines, and much more.

Citations and References

Documenting sources : advice on citing information from outside sources in the body of the report and listing those sources of information in the References section at the end of the report.

Additional Resources

Writing a Research Proposal

A step-by-step guide that takes you through the process of writing a research proposal.

Labwrite for Middle School

Labwrite activities for students in the middle grades.

Sample Lab Reports

Examples of lab reports that illustrate how the parts of the report are written and arranged. Use this to see what a completed lab report looks like.

Glossary

An alphabetical list of words and phrases with their definitions as used throughout LabWrite.



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