The Student Lab Report Handbook

A Guide to Content, Style, and Formatting for Effective Science Lab Reports

Second Edition

John D. Mays

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Chapter 1
Using a Lab Journal

1.1 Why Lab Journals Are Important

Scientists engaged in experimental research keep detailed journals documenting every aspect of their work. Because of the importance of journaling in the scientific community, and because of the close connection between journaling of scientific experiments and the need for science students to develop excellence in written expression, each student in a laboratory science course must maintain a thorough lab journal.

The lab report is the final product documenting a laboratory exercise and is submitted to the instructor for grading. During the experiment itself, you must individually record your activities, observations, and the data acquired by you and your team in your lab journal. All of the information from the experiment that you will need later to write the lab report should be written in the journal at the time of the experiment. Later, as you are preparing your report, the lab journal is your source for all of the information that you will present. You should never rely on memory alone or on notes kept by other team members to document your work. Your instructor may require you to submit your lab journal with the report for grading, or it may be checked and graded separately.

Good choices for lab journal use are the National 53-108 hard cover, or the Mead 09127 flexible composition book shown in Figure 1-1. Both of these contain quadrille (graph paper) pages, which facilitate the tabulation of your experimental data and the construction of any graphs or diagrams you may need to draw during the laboratory exercise. Any similar composition book with quadrille pages will suffice. Do not use a spiral-bound notebook, a three-ring binder, or any notebook with ruled paper.

Figure 1-1. The Mead 09127 composition book.

1.2 Pencil or Pen?

In the first edition of this book, I strongly encouraged students to use only pencil when writing in their lab journals. This is because I encourage students to use pencil for everything else in their science and math classes. However, I learned something new since that edition was published—practicing scientists now use only indelible (that is, non-erasable) ink in their lab journals. As described above, lab journals are the primary record of experimental work. Sometimes a scientist's lab journals become key evidence in cases of establishing priority in a discovery or in identifying crucial details that could affect the outcome of a patent-infringement lawsuit. When documents are of such importance, it is of paramount importance that they are written in indelible ink. For this reason, I now encourage students to use only blue or black ink in their lab journals and pencil for their other work in science and math. (Colors other than blue or black are not acceptable.) Ultimately, your teacher will decide whether you are required to maintain your lab journal in ink or if pencil is acceptable. But my view now is that as a student, you should develop the habits of a real scientist. This means maintaining your lab journal in ink.

Maintaining lab journals in ink obviously introduces a bit of a problem. Your journal is to be neat and free of smudges, doodling, stray marks, and so on. So what do you do if you discover that you made an error? For example, what if an entire table of data is full of wrong entries? You do exactly what a practicing scientist would do—you *carefully* circle the incorrect information (in ink), and *neatly* cross through it with one line. You should make sure what you cross out remains legible. Make a note as to why it is to be ignored, and put the date and your initials on the note. This way, it is evident to everyone that you knew at the time that there were errors and you made note of them. You want to avoid the possibility of someone thinking that the data were changed later, after the fact.

Now, you may be thinking that all this formal lab journal stuff is goofy. You may think that you are just a student taking a science class and have no intention of become a practicing scientist, so there won't be any patent-infringement lawsuits over your lab work. Well, you never know where you will end up. Plenty of people change their majors halfway through college. So every student needs to learn proper scientific laboratory methods. And the right time to begin learning those methods is *right now*. This applies whether you are in junior high, high school, or college.

1.3 General Lab Journal Principles

The following principles apply to everything you write in your lab journal.

1. Every time you make an entry in your journal, the entry should be dated and well-organized. As suggested by Figure 1-2, it is imperative that lab journals are kept neat, clean, and free of extraneous marks or doodling.
2. When you write the date, make the date unambiguous by spelling out the month, as in the dates 6 February, 2014 or February 6, 2014.[1]
3. Begin a new page in your journal for each experiment.

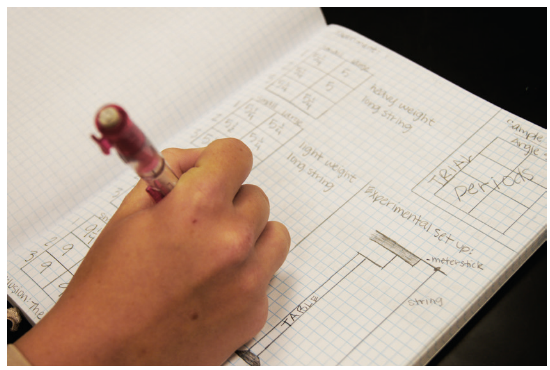

Figure 1-2. Keep your lab journal exquisitely neat.

4. Do not leave blank pages or space in your lab journal. If there is blank space remaining at the end of an experiment, *neatly* cross through it. This way no one can go back and add in information that wasn't part of the work at the time.
5. If you have printouts, photographs, or other loose items, tape them into your journal and sign and date the entry.
6. Your journal should contain only information and data from work where you were present and personally involved. If you need information from a teammate pertaining to a day when you were not present, enter the information and make a note of where the information came from and when you transcribed it into your journal.
7. Put your name and contact information on the front of your lab journal.

1 This is because Europeans write the date before the month in dates, whereas Americans write the month first. To an American, 2/6/14 means February 6. To a European, it means June 2.

1.3 What to Write In Your Lab Journal

Examples of the kind of information that you should enter in your journal are listed below.

1. Date of entry.

   Every entry must be dated so you can retrace what happened if something turns out wrong or if you later find that you have conflicting information. As mentioned above, make the date unambiguous by spelling out the month. Include the time of day only if it happens to be relevant to the experiment.

2. Names of other people working in the team.

   List the first and last name of everyone who worked on your team that day. List the names separately for each day you work so that you know exactly who was present and when.

3. The purpose or goal of your experiment.

4. Your experimental hypothesis.

5. Lists and quantities of all equipment, materials, and supplies used.

   Be sure to include the makes and model numbers of all electronic equipment or major apparatus. This may not seem necessary for a school science class, but it is standard practice among scientists and you need to get in the habit. When different teams of scientists compare experimental results, an important factor will be to see if any differences in experimental results are attributable to differences in the mechanical or electronic equipment. Now is the time to develop good habits for documenting the equipment used.

6. Tables documenting all data taken during the experiment.

   As you record data, it is crucial that you record the units of measure as well. Always record the units of measure in the same units as displayed by the measurement device. If you need to convert your data into different units, then it is a good idea to make another column in your journal for the new values converted to different units. (Also record the unit conversion factors or equations you use). In your report, you should show both the original units in which the data were collected and the converted values you need for the calculations you must perform.

   You must also record all data using the correct number of significant digits for the measurement instrument you used. If you measure out 8 mL of liquid, you need to record this value as 8.0 mL, 8.00 mL, 8.000 mL, etc., depending on the precision of your measurement instrument. Do not simply write 8 mL unless your measurement actually was made with only one significant digit (which won't happen).

7. Detailed records of all qualitative observations.

   Experimental observations are often chiefly documented by data. But any nontrivial qualitative observation you make that relates to the experiment needs to be documented as well. This is true in any science course, but it is especially common in biology and chemistry. Qualitative observations you may need to document involve color, appearance, texture, odor, action (such as what happened or did not happen in certain circumstances), taste, or other observations.

8. Descriptions of steps or procedures followed, problems encountered, solutions implemented.

   Write down exactly what you and your team do. All standard procedures should be documented. If you encounter a problem, you should document it. If you have to do some work over again because of an error or an unexpected experimental result, you should document it and explain what happened. If you think of a good way to work around some unexpected problem, you should document that, too. (Your teacher will appreciate that.)

9. Preliminary calculations, or calculations needed during the procedure.

   Sometimes you will need to use data collected in an early part of a procedure to perform calculations prior to continuing with the experiment. These calculations should all be documented in your lab journal. Your lab journal is also the proper place to document the calculations you make after all the data have been collected. These final calculations can then be typed into appropriate tables in your lab report.

10. Diagrams of apparatus and experimental setup.

    If your experimental setup was simple enough that it can be explained in a few sentences, a diagram is probably not necessary. If the setup is complex and cannot be clearly described in a paragraph or two, then a diagram or photograph of the setup is needed. If you take photos, be sure to document whose camera, phone, or computer the photos are on so that you can find them later.

11. Preliminary graphs which may be needed during the experiment to assess progress.

    If you need to make a preliminary graph of your data to get an idea of how the experiment is progressing, the lab journal is the proper place to do it—not on a piece of scrap paper.

12. Names, phone numbers, and reference information.

    If you have to contact anyone outside your immediate experimental team, such as a supplier or scientific expert, then that person's contact information, as well as the information you obtained from that person, should all be documented in your lab journal. Think of it this way: In a real working research lab one frequently needs to consult with a manufacturer's representative or an experienced person at another lab. Whatever information is obtained needs to be documented for the benefit of those who continue to work in the lab after you are gone. In our journals we need to make it easy for those working after us to retrace our steps, to follow up with new questions that may need to be posed to previously contacted experts, and so on. This kind of information can be critical and can save future researchers a lot of time. So, as mentioned above, now is the time to develop good habits. If you have to contact anyone about your work on a particular project or experiment, document the contact thoroughly. Write down how to reach them, what they told you, notes about any materials they commit to send to you, and so on.

13. Locations and/or sources of printed reference materials.

    Any reference materials used during the lab, or which come to your attention during the lab and may be needed later, should be documented. This is both to have the reference information you used during the experiment, as well as to remind yourself of resources you might need that you may forget about later.

Chapter 2
Formatting and Printing Requirements

2.1 The Importance of Proper Formatting

The way your report looks is extremely important. In scientific work, there are common practices that govern everything about the way scientists document their work. If you write a scientific paper that is to be published, the formatting requirements for that article will be extensive, detailed, and rigorously enforced. For these reasons, part of your laboratory experience in your present laboratory course is to produce lab reports that meet a very specific set of formatting and content requirements.

These requirements were not just invented to make your life hard. The requirements specified here are designed to teach you how formal scientific papers are formatted. If you intend to enter into a branch of scientific study, writing reports according to the specifications described here will help you prepare for that work. But even if you don't intend to be a scientist, there is still great value in mastering the report requirements in this book. Most students have to take a laboratory science course in college, and if you already know how to prepare a proper lab report, you will reap the benefit. Further, in just about every professional field, people have to write reports. Learning the basics of scientific reporting will make it much easier in the future for you to learn how to write reports in your other classes or for other kinds of work.

2.2 Formatting Requirements for Lab Reports

Your printed report must meet the following requirements:

1. Margins and line spacing.

   Reports must be typed with single-spaced text and printed on white paper using one-inch margins.

2. Fonts.

   Use a plain font such as Times New Roman. The point size for the text should be 12 pt. When setting up graphs in a program such as Excel or Pages, it is common for the default fonts in axis labels, axis scales, and so on to be a sans serif font such as Arial. It is permissible for these kinds of labels in graphs or other figures to be either Times New Roman or Arial.

3. Labels and titles on tables, graphs, and figures.

   Formatting requirements for the labels and titles on tables, graphs, and figures are discussed in Section 3.4.

4. Reference citations.

   Formatting requirements for citations in the References section of the report are discussed in Section 5.9.

5. Colors.

   Do not use color for your report text; the text of your report must be entirely in black and white. You may print your report either in color or black and white, unless you have photographs or other figures that require color for them to be read properly. However, note that graphing software in Microsoft and Apple products automatically uses different colors for multiple curves displayed on the same graph. If you will be printing in black and white, these colors will not be distinguishable. To make the correspondence between the legend and the graph work in black and white, the symbols used for the data points on the two curves must be different. In some applications the default symbol shapes for all data are the same, and the graph depends on color to distinguish the curves from each other in the legend. For black and white prints, you will need to determine how to change the symbol shapes for each data set (each separate curve) and make the symbols on each curve different from the symbols on the other curves.

6. Extra graphics.

   Reports should look clean, neat, and plain, with crisp formatting. Do not attempt to dress up the appearance with fancy graphics, title pages, colors, and so on. Plain is good.

7. Stapling.

   Do not enclose the report in a binder or plastic cover, and do not use a cover sheet. Simply staple the pages together in the upper left hand corner.

8. Technology problems.

   Do not submit a report that contains errors due to your software or printing technology. You are expected to proofread your report and identify and correct any errors in your printed report that are due to computer or printer problems. For example, it has happened when copying a graph from a spreadsheet to a word processor that only half the graph appears after it is pasted in. Low-resolution graphics and equations may be seriously fuzzy or even illegible, depending on your software and your printer. Sometimes your printer cartridge runs out of toner in the middle of a page and the page fades out toward the bottom. You should not turn in a report containing these kinds of errors.

2.3 Planning Ahead

After spending a lot of time and effort putting together a high-quality lab report, the last thing you want is to find out at 1:45 a.m. that you are out of printer paper, or your printer is out of toner, or some other disaster. You should always plan your work so that if you have technical difficulties you will have time to get them resolved prior to the report due date. In general, you should prepare your report far enough in advance so that you have time to proofread, make corrections, find a different printer, get help with graphs, and so on, rather than waiting until the night before the report is due.

Chapter 4
Report Content Overview

This chapter contains a general outline that you can use to design a good report. In the following two chapters (5 and 6), you will find more detailed discussion of the contents for each section in the report.

4.1 Assumed Audience

As you put together your section content and decide what to say, assume that your reader is an intelligent person who is mathematically competent and who has a working scientific vocabulary, but do not assume that the reader was present at the experiment or has any idea of what the experiment was about. In other words, imagine that you are explaining your experiment to a teacher in another department or to a working professional. If it would be silly to explain something to such an individual (such as what length or volume are), then the explanation is probably out of place in your report. If an explanation of something seems necessary so that the individual would know what you are talking about, then that explanation probably does belong in your report.

4.2 Heading

The heading at the top of your report should include a title for the experiment, your name, the names of the other members of your experimental team, the date the experiment was performed, the date the report was submitted, the instructor's name, and the name of the class.

4.3 Abstract

Your instructor will tell you if an abstract is required. Abstracts are usually required in upper-level or advanced courses. The abstract is a very brief or even terse summary of the goal of the experiment, what was done, and what the results were.

4.4 Purpose

Here you state the purpose of the experiment in one or two sentences. Laboratory experiments are of two general types—those designed to test a hypothesis and those designed around students' exploration and discovery. These two general types of experiments have different purposes. Experiments in physics, and often in chemistry, are hypothesis-driven. In a hypothesis-driven experiment, one seeks to measure an experimental result (often the value of one or more particular variables) and compare it to the value predicted from the theory. In this case, the purpose statement should be about experimentally determining the value of a variable and comparing this experimental result to the values predicted from the equations in the theory. Here is an example purpose statement for this type of experiment:

> "The purpose of this experiment was to measure the rate of heat transfer out of a blackbody at certain conditions and compare experimental data to rate predictions based on the Stefan-Boltzmann law."

On the other hand, experiments in biology, earth science, astronomy, and sometimes chemistry are often discovery-driven, and are oriented around exploration and discovery rather than making specific predictions. In these experiments, the purpose statement should be about the goal of the exploratory process. State this goal as specifically as possible. Here is an example purpose statement for this type of experiment:

"The purpose of this experiment was to identify eight constellations and document their positions on the celestial sphere."

4.5 Background

The goal of the Background section is to inform your reader about the experiment so that your reader will have a clear idea of what you did, why you did it, and what your results mean. This section should include the elements below in the order listed. For high school science reports, this section of the report will require from one to four paragraphs (maybe more), depending on how complex the theory and the experiment are. In college lab classes, the background may need to be much longer, and your instructor may want the historical comments to be limited to the history of research efforts on a very particular scientific problem. At the high school level, historical information will be more general.

Quoting dictionary definitions is something grammar school students commonly do, but it is bad form for more advanced students. If you are using a common term, a definition is not necessary. If you are using a specialized term, then it is better to quote a definition from a technical source (such as a text) with an appropriate reference citation rather than from a dictionary.

In the Background section do not go into any specific calculations or measurements. Do not discuss anything that actually happened during the experiment. All of that comes later. Keep your comments general but informative.

1. History

   If your experiment relates at all to principles discovered in the past, always begin with a bit of history, but make your comments brief and specific to the theory or law you are working with. This is not a history paper, and it is not the place to paste in a load of quasi-irrelevant information you copied from a website. Focus on how and when the law you are investigating was discovered and the vital steps of discovery that inform the work you are presently engaged in. A line or two of biographical information about the individuals behind your theory is appropriate, but avoid extended, random biographical information that is not directly relevant to your experiment. Always cite your sources using the formatting standards your instructor requires (see the References section in the next chapter).

2. Theory

   Describe the theory your experiment is based on. If the theory includes equations, state and explain them here. Also explain what they will be used for in your experiment and what the variables mean in each one. If you need to express equations in different forms to assist with your description of your theoretical approach to this work, do so, but do not describe the tedious details of the mathematics. For example, it is appropriate to write:

   "Newton's Second Law of Motion, $F = ma$, can also be written as $a = \frac{F}{m}$."

   But do not write:

   "Newton's Second Law of Motion is $F = ma$. If we divide both sides by m and cancel the m's on the right-hand side we get $a = \frac{F}{m}$."

   Remember, your reader is an intelligent person who is mathematically competent and has a working scientific vocabulary. Your reader doesn't need an explanation from Pre-Algebra about how to solve an equation for a variable. On the other hand, if you used unique or sophisticated solution methods these should be described in some detail.

3. Overview of experimental plan

   In a few sentences, outline the general approach you followed in the experiment and the major pieces of equipment or apparatus you used. The goal here is that the reader has a basic idea of what is going on so that your description later of the detailed procedure will make sense. If, after reading this part, the reader still does not know why you did certain things, then this section is not adequately developed.

   If you are using a theory to make predictions, explain how this will be done. It is appropriate to do this here, after the experimental plan has been explained.

4. Hypothesis

   Conclude the Background section with a specific statement of your experimental hypothesis, written in the past tense. The hypothesis statement will only be present in hypothesis-driven experiments, where your team forms a hypothesis and then performs the experiment to confirm or disconfirm that hypothesis. By contrast, in a discovery-driven experiment (such as a dissection in biology), there is no hypothesis. There is simply the goal of the work that you stated previously in the Purpose section.

4.6 Experimental Procedure

In this section describe *what you did* but not *what happened*. Begin this section with a list of the equipment and supplies used in the experiment. Then describe your experimental procedures and methods in detail. Watch your verb tenses and strive to make your methods crystal clear to the reader. This will be easier to do well if you generally avoid using pronouns. As described in the previous chapter, some instructors require this section to be written in the passive voice.

Do not present data in this section, and do not get into describing or interpreting your results.

4.7 Results

In this section, describe *what happened*, that is, what the results were of the procedure you just described. Present your data in tables. Label and title them, and refer to each of them in order in the text before they appear. If you were required to make qualitative observations during the course of the experiment, describe them here. Do not begin interpreting your results here; that is to be done in the Discussion section. Here just state what happened.

Don't forget to present every value of every variable. Often there is a single value (such as a mass, a height, or a concentration) that is used in multiple trials. If there are only one or two such values, they probably aren't worth making a table for, and this makes it easy to forget to state them at all. Also, make note that data values can never simply appear on a page. They must either be stated in a complete sentence or placed in a table. And always, always state units of measure. Every time.

4.8 Discussion

Before getting to the details on the content for the Discussion section of your report, we need to establish how to approach the calculation universally and incorrectly referred to as the *experimental error*. I have a different term I like to use, and which I encourage other teachers to use. Of course, you should use the terminology preferred by your own instructor. We will discuss this terminology first and then move on to the other details of the Discussion section.

Percent Difference

One of the conventional calculations in laboratory science courses is the so-called *experimental error*. Experimental error is typically defined as the difference between the predicted value (or accepted value) and the experimental value, expressed as a percentage of the predicted value, or

$$\text{experimental error} = \frac{|\text{predicted/accepted value} - \text{experimental value}|}{\text{predicted value}} \times 100\%$$

Although the term *experimental error* is widely used, it is a poor choice of words. When there is a mismatch between theory and experiment, error in the experiment may not be the source of the difference. Often, it is the theory that is found wanting—this is how science advances.

I now prefer to use the phrase *percent difference* to describe the value computed by the above equation. When quantitative results can be compared to quantitative predictions or accepted values, students should compute the percent difference as

$$\text{percent difference} = \frac{|\text{predicted/accepted value} - \text{experimental value}|}{\text{predicted value}} \times 100\%$$

As you see, the calculation is the same. This issue is simply about what we will call this calculation. Again, if your instructor wants you to stick with the conventional use of "experimental error," you should do so. But in the rest of this manual, including the example reports in Chapter 9, I will use the term *percent difference*.[1] In Section 6.4, we will look at a specific case where error originates in the theoretical model and not in the experiment.

Discussion Section Content

The goal for the Discussion section is to analyze and discuss your results, explain whether your hypothesis was confirmed, spell out what you learned, and judge whether your results were definitive or inconclusive, regardless of whether the hypothesis was confirmed.

The outline below will work successfully for many standard lab reports. However, the issues addressed in this section do not necessarily need to be treated in this exact order. More advanced writers should feel free to tailor the structure of this section to suit your own work.

1. If your experiment involved calculating predicted values, present these. Use a table for these values unless there are only one or two values. Always state the units.
2. If your report includes any graphs or diagrams that are discussed in this section, you should present these next. As with tables, graphs, and figures referred to earlier, label these, title them, and refer to them in the text. Comment on your graph, its characteristics, what it tells you, and whether it appears as expected. For graphs or diagrams that occur in longer, more sophisticated reports (in which the Discussion section is much more than just a paragraph or two), placement

1 I ceased using the term "experimental error" in early 2013. Earlier editions of my texts include that language. The language is different in newer texts.