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Organizing a Laboratory Notebook

Introduction

Congratulations! Now that you have written your research proposal and have a clear plan for your research project, you are ready to organize a notebook for recording the data you will collect from your research experiment. A *laboratory notebook* is an organizational tool that you will use to store and record all aspects of your experimental research project. I use the term *laboratory* in a general sense to include experiments that are done outside the laboratory setting. After all, the world is our laboratory!

Learning Objectives

The main objectives of this chapter are for you to create a laboratory notebook for your research project and to identify and construct data tables specifically designed for your project.

Also, by the end of the chapter you should be able to

1. explain the importance of keeping an accurate laboratory notebook and
2. explain the pros and cons of paper laboratory notebooks and the pros and cons of online laboratory notebooks.

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Key Terms

Laboratory notebook: An important organizational tool for the researcher; used to store and record all aspects of the experimental research project, including procedures, data, statistical outcomes, graphs, and conclusions.

Raw data: The numerical data collected during an experiment before calculations or statistics have been applied to these numbers.

Purpose of Laboratory Notebooks

The laboratory notebook has three main purposes, which dictate its organization and its contents.

1. The laboratory notebook is where you store experimental research procedures, data, statistical outcomes, graphs, and conclusions.
2. The notebook is a place for you to record thoughts you have about the experimental design and any inferences you have regarding possible outcomes of the data you are collecting. In this sense, the notebook is a journal or a place where you talk to yourself about the experiment.
3. The notebook serves as an official record of the experimental project as a whole. Someone else should be able to pick up your notebook and (a) undertand how you performed the experiment and (b) be able to replicate it exactly.

Although there are software programs that help researchers organize their research projects (see pp. 79–80), most researchers still prefer paper versions of the laboratory notebook. In this chapter, I'll primarily discuss paper notebooks but will address technology adaptations as well.

Paper Laboratory Notebooks

Because the notebook is an offical dated record of the experiment, researchers put a strong emphasis on (a) using laboratory notebooks constructed in such a way that they reduce a researchers's temptation to tear out pages, (b) using permanent pens (i.e., those that do not bleed, such as pens you might use on ceramics), and (c) not using correction fluids or tapes. Buy a notebook where the pages are sewn into the binding. Composition notebooks work well and are inexpensive. "Official" laboratory notebooks are also available for purchase from companies like Book Factory, Scientific Notebook Company, and Amazon.

Do *not* purchase sprial notebooks or three-ring binders. It is too easy to remove pages that you think show undesirable or unfavorable data in light of your hypothesis. Removing evidence of procedural mistakes or data that do not support your hypothesis is highly frowned upon in the scientific

community. The notebook should record everything regarding the experiment because you never know what may be significant. Therefore, never rip out any page of your laboratory notebook.

Because laboratory notebooks will include graphs and other items that may be printed from the computer, having a notebook large enough to accommodate these computer printouts is a necessity. The printouts will be glued or adhered to the pages within, so you will either have to reduce the font to make it fit or buy a notebook slightly larger than 8 ½ × 11 in. to accommodate these inserts (art supply stores are good places to find larger notebooks). In addition, be sure to find a pen that does not bleed when it gets wet. If you make a mistake when entering something into the notebook, just draw a single line through the word(s) and write the correct word(s). Don't use correction fluid or "obliterate the entry with an ink blob" (Purrington 2009, p. 33).

Online Laboratory Notebooks

Some scientists frown on the use of technology for a laboratory notebook. Two of the arguments against organizing and storing this important information electronically are (1) it is too easy to modify data or to remove undesirable results, and (2) the confidentiality and safety of the information are uncertain. However, because both wikis and Google Docs have a history function, any changes made to the web pages or documents are recorded, date stamped, and attributed to the person who made the changes. Therefore, data changed, added, or deleted is recorded. The confidentiality issue is a bit more complicated. However, advanced features of wikis allow them to be private and readable only by their members. Google Docs have various privacy settings as well, but one should be cautious and assume that anything posted to the web can be viewed by anyone. Overall, as long as individuals' names or personal identifying information is not recorded online, posting data collected as part of a high school project should not be a problem.

If you have consistent access to a computer with reliable internet service, you may want to consider having your laboratory notebook online. (Online laboratory notebooks also make sense to those of you working in groups. See the Data Collection Issues for Groups on p. 80 below for more information about this.) The purpose of the notebook is exactly the same as the paper version, but instead of attaching printouts to pages or directly recording data into a paper notebook, you organize, post, and link the same information online.

You first need to consider what online space will be the portal to your entire notebook. This most likely will be a web page. It could be a page you design yourself from scratch or it could be a wiki-like program. When constructing these pages, consider privacy issues and how much control you

have over who can view your pages or, in the case of a wiki, who can make changes to them. (If you are designing a wiki and working in a group, all group members must have wiki accounts and be given special permission to make edits. It is likely that your instructor may also want editing privileges so that he or she can leave you comments and feedback.)

When organizing a laboratory notebook online, follow the suggestions given in the Components of a Laboratory Notebook section of this chapter (pp. 82–91). For starters, each section heading will be its own web page, with links easily accessible in a navigation area of the website. The keys to making a functional online laboratory notebook are (a) linking to appropriate pages within the wiki and (b) organizing links to additional notebook components logically.

(*Note:* The safety of the information posted online could be a concern. Just as you could lose your paper laboratory notebook, something could happen to the online laboratory notebook. You can reduce the likelihood of this tragedy by backing up the wikis and Google Docs files weekly.)

Data Collection Issues for Groups

If you are conducting research as part of a group, you will find that the data collection component has three challenges: (1) where the experiment will be conducted, (2) how to assign tasks to group members, and (3) how to organize a group laboratory notebook.

Determining the Location of the Experiment

First, you will need to consider where the experimental setup will be. It is ideal if you have a communal space you can use at school. That way, all members can have regular contact with the experiment. However, it is possible that the experiment will need to be set up at the home of one of your group members or at some other site. If you have a choice in this matter, choose a location that allows the most group members access to the experiment.

Assigning Tasks to Group Members

Second, it is important that all group members participate in data collection. At your first meeting, you should make a list of (a) the tasks that are involved in setting up the experiment and (b) the data collection tasks that will be required once the experiment has begun. Here is a general list to get you started, but your list should also include very specific tasks that are necessary for your experiment.

- Purchase or otherwise obtain laboratory equipment
- Organize the laboratory notebook (before the experiment begins)
- Measure and record quantitative data
- Write and record qualitative (descriptive) data
- Ensure that experimental procedures follow proposed methods
- Monitor possible influence of external variables
- Monitor safety and ethics issues
- Contact the teacher or mentor with questions (one person in the group should be assigned this task so that the teacher or mentor is not inundated by all group members with identical questions)
- Take photographs and label them in the laboratory notebook

Once you have a list of tasks, talk openly with group members about what you personally would like to do. The goal is to evenly distribute tasks, taking into account the strengths of each member. If one group member enjoys organization, assigning a task to this member, such as designing data tables for the laboratory notebook, will enable the group to be more efficent. If another member says that he or she is detail oriented, that person might be given the quantiative data collection tasks. Each member, however, will have multiple tasks and, therefore, *you will probably have a task that does not match what you are best at. Working in a group includes taking on tasks that stretch you as an individual.* Once your group agrees on which tasks each member will perform, you might consider assigning offical individual titles—for example, Notebook Manager, Quantitative Data Recorder, Descriptive Data Recorder, and Experimental Design Monitor.

As you assign roles to each group member, be sure that the distribution of tasks does not compromise your experimental design by adding external variables. For example, it would not be a good idea to rotate tasks among group members every two weeks in order to equalize the work load. Individuals might have slightly different techniques that could introduce variations into the experiment. It is better to assign specific tasks to one individual who performs those tasks throughout the entire experiment.

Once tasks and roles have been agreed on, write up a contract and have each group member sign it. Give a copy of the contract to your teacher so he or she can keep track of what each group member is supposed to be doing. Also, put a copy of the contract in the laboratory notebook so you can refer to it throughout the experiment.

Organizing a Group Laboratory Notebook

A third issue to address when working with a group is whether each individual will keep a separate notebook or if the group will keep one consolidated notebook. There are pros and cons to each.

Reasons for Keeping Individual Laboratory Notebooks (Paper or Online)

- Ensures that you will have to communicate with your group members
- Creates accountability on an individual basis.
- If one notebook is lost, other group members still have copies.
- Encourages individual members to record inferences that may differ from those of other group members.

However, keeping individual notebooks is not convenient if the experiment is located off site, and each member has various roles in the data collection.

Reasons for Keeping Group Laboratory Notebooks (Paper or Online)

- All data are in one location. Each group member is responsible for performing tasks and entering data as assigned to him or her.
- If the notebook is online, all members have access to it no matter where the experiment is being conducted.
- If the notebook is online, one member can post assigned tasks to the appropriate portion of the notebook and other group members can enter data *simultaneously.*
- Group notebooks foster collaboration among group members because each member can post comments and inferences as the experiment is conducted.

However, if one member of the group does not have as reliable online access as the others, it may be difficult to distribute the tasks evenly or to expect equal collaboration.

Components of a Laboratory Notebook

Although researchers organize their laboratory notebooks differently, there are certain basic components that are found in most notebooks (Beavon 2000;

Gordon 2007; Karnare 1985). For our purposes, your laboratory notebook will be subdivided into seven sections. The headings for these sections will be as follows: Title Page; Table of Contents; Experimental Proposal; Record of Procedures; Record of Correspondence; Data Tables; and Graphs, Statistical Analysis, and Conclusions. These sections are the suggested minimum for a laboratory notebook. With the approval of your teacher, you can add, remove, or rename section headings to better fit your experimental design.

Title Page

The Title Page is the first page of your laboratory notebook and should be dedicated to providing introductory information about its contents. Most important, write the title of the experiment along with the dates the experiment will be conducted. Below this, write your full name, address, contact information (either your e-mail address or a phone number), school name, and teacher name. This will help the notebook find its way back to you should it be misplaced. For online laboratory notebooks, the title page is simply the home page of your website. However, do *not* post personal contact information online and be sure to follow any additional restrictions your school has for posting identifiable personal information.

Table of Contents

The next two pages should be reserved for the Table of Contents. Here you list the section headings as well as the page numbers on which each section begins. Therefore, you will need to number every page of your laboratory notebook; do this when you first get the notebook. Use the seven section headings listed in this chapter (unless you have made other arrangements with your teacher). You may also need to add subsection headings. For online laboratory notebooks, write a paragraph on the home page/title page explaining how to navigate the online notebook. This paragraph will accomplish the same function as a table of contents.

Experimental Proposal

The next section, under the heading Experimental Proposal, should be a record of the design proposal your teacher approved. Therefore, this section will include a project title, an introduction (if it was required), an experimental design table, your hypothesis, materials, methods, and possibly an appendix.

Since the proposal was typed, you will need to reduce the font or page size so that you can directly attach each page of the proposal on a single notebook page (rubber cement or scrapbooking adhesives work best). Don't attach a

stapled packet that needs to be unfolded to be read. You want to have quick and easy access to this document. For online laboratory notebooks, you may choose to copy and paste your proposal directly onto the Experimental Proposal web page, or you could provide a link to a Google Doc. Uploading the proposal as an attachment is not recommended because it is not as quickly accessible.

Record of Procedures

Next, your laboratory notebook will include a section with the heading Record of Procedures. Reserve a large section of blank pages to be used for this section. When you begin your experiment, you will refer often to the methods section you wrote for your proposal. In the Record of Procedures section, you record the date and a detailed description of what you completed each day of the experiment. It is critical to record detailed and accurate entries.

The pages of this section should be organized to look something like Table 6.1. Notice several aspects about this setup. The first column is labeled "Day of Experiment"; the second column is for the *calendar date*. The information in the first column is particularly helpful because, in your discussion of the results, you will be asked to refer to the experiment day, not specific dates.

Rows can remain blank if the experiment is not attended to daily. If you want to, use the pronoun *I* in the column headed Procedures Completed. If for some reason, you must be away on a day when you had intended to work on your project, have someone else collect data, take measurements or readings, and perform tasks to maintain the environment. If that happens, write down the name of the person who performed the tasks on those days (at the end of his or her entry). This information might prove to be significant later on in the research process. For online laboratory notebooks, the Record of Procedures could be directly on the web page or it could be a link to a Google Doc.

Accuracy and detail are extremely important when recording the procedures. They make you accountable to yourself and to your teacher as well. Your teacher will occasionally ask to see your laboratory notebook and will refer to this Record of Procedures section to be sure that you are in fact doing what you proposed to do and that you are writing down these procedures in sufficient detail.

Record of Correspondence

The Record of Correspondence section of your laboratory notebook is for documenting any correspondence or communication that relates to your experiment. Most likely the communication will be between you and your teacher or mentor. This documentation is important because it might include advice or suggestions for how to continue or modify your experimental design after

Table 6.1

Sample Record of Procedures

Day of Experiment	Date	Procedures Completed
1	Mon. Oct. 7	Set up control and experimental groups. (Notice that the day you set up the experiment is day 1).
2	Tues. Oct. 8	Watered control group and experimental group #3 until the water ran out the bottom. After 10 minutes I emptied the saucer.
3	Wed. Oct. 9	-- --
4	Thurs. Oct. 10	Added more soil to experimental group #2 (Fluffy, my sister's cat, tipped it over!)
5	Fri. Oct. 11	-- --
6	Sat. Oct. 12	Watered all groups—used same procedure as 10/8

the experiment has begun. Put summaries of these interactions in a list that is organized similar to the Record of Procedure table. For both written and face-to-face correspondence, record (a) the date of the interaction, (b) a detailed description of what you discussed, and (c) what conclusions you and your teacher or mentor reached. If you received permission to modify your proposed methods, be sure to provide an explanation of why this change was considered to be necessary.

If you are working with a mentor, you will probably have e-mail exchanges regarding your research. Classroom teachers may also provide feedback electronically. These written interactions should be printed out, dated, labeled, and directly attached into this section of your laboratory notebook. Therefore, save extra blank pages for these exchanges to be included in this section. You should still write summaries of the correspondence into the dated list, but then refer to the printed documents as shown in the second entry in Table 6.2 (p. 86).

If you are working with a group, it is important that any discussions that directly affect the experiment are recorded in the Record of Correspondence section. One entry might be if the group assigned or changed roles for each member; this should be documented as shown in the first entry of Table 6.2.

For online laboratory notebooks, the Record of Correspondence table could be directly on the web page (or in a Google Doc) and the Record of Correspondence could be an additional page or link. You could put copies of the e-mails (copied and pasted) right onto the additional pages. Remember to date and label each e-mail. Enter summaries into the table, refer to the e-mail, and then create a link directly to the e-mail copy.

Table 6.2

Record of Correspondence

Day of Experiment	Date	Procedures Completed
Prior to start of experiment	Thurs. Oct. 3	Group decided to divide the data collection workload. I (Jose) will be the laboratory Notebook Manager, in charge of setting up and maintaining the online Laboratory notebook space, making sure all group members enter data as scheduled, monitoring the experiment for possible influence of external variables, and recording any correspondence. Sam will be the quantitative Data collector in charge of taking and recording all measurements into the data tables. Shawna will be the descriptive Data Collector in charge of writing and entering descriptive data into the data tables. See signed contract for full details.
6	Sat. Oct. 12	When the experimental groups of bacteria cultures showed no sign of growth in the first 5 days of our experiment, I emailed our mentor (see email #8). Because the control plate is growing adequately we suspected that we had inoculated the plates correctly, but that maybe the concentrations of the experimental group were too strong. He then helped us recalculate concentrations so that we can inoculate new plates with the new concentrations early next week.

Data Tables

A large section of your laboratory notebook will be the Data Tables section. This is the space dedicated to recording data from your experiment. It is important that this section be well organized. (*Note:* Never jot down data in some random place with the intention of transcribing the data later into the notebook. You probably won't remember to enter that data.) Before you begin your experiment, you should spend some time thinking about the data you plan on collecting because the types of tables you decide to use are determined by the research design of your experiment. Refer to Tables 6.3 and 6.4, which suggest ways to organize your data in data tables.

Both raw data and descriptive data are best organized into tables or cells. The data that you collect during your experiment is referred to as *raw data* because no calculations or statistics have been applied to these numbers. These tables can be constructed in a word-processing program, printed out, then permanently attached within the Data Table section of your laboratory notebook. Or you can draw the tables by hand directly into the notebook.

If your laboratory notebook is online, you have several options. Word-processing files, as well as spreadsheet files, can be posted to Google Docs. Just be sure to organize these files all in one space and make sure that they are correctly linked. For example, if you organize your laboratory notebook in a wiki, you would have an entire page titled Data Tables. On the Data Tables page, you could have links to each of the data tables where data is being entered. Although you could design tables directly on wiki pages, it is ideal to link to word-processing or spreadsheet files posted in Google Docs because several individuals can be working in the document simultaneously. No matter how you choose to organize your data, be sure to design these tables specifically for *your* experiment.

Because you are collecting different types of data, you will most likely need to design various tables with different organizations. For example, you may be collecting several quantitative measurements, along with several descriptive observations. The example shown in Table 6.3 puts both quantitative and descriptive data together in the same table. Notice that the data is for just one entity. This type of data organization requires that each entity be recorded in its own table (rather than all entities being recorded in the same table).

The data table example shown in Table 6.4 (p. 88) describes only qualitative (descriptive) data. This means you would put the quantitative data in another table. This method of organization allows you to write out your inferences or your explanation of why you think the data are occurring the way they are. These inferences should be based on (a) what you are observing **and** (b) what you learned in your background research. Having an inference

Table 6.3

Sample Quantitative and Qualitative (Descriptive) Data Table

Day #	Date	Quantitative Data		Qualitative Description of the Plant, Including Environmental Change
		Leaf Length (mm)	Leaf Width (mm)	
1	Mon. 10/7	88	15	Leaf is dark green in the center, but edges are crispy and beginning to turn brown.
2	Tues. 10/8	89	15	Dark brown edges are more noticable and have grown toward the center of the leaf.

column may help you when you go to analyze your data because you have been recording your thinking all along during the experiment.

Table 6.5 is an example of a quantitative data table of someone who thinks ahead! Notice that the bottom row contains a place where total changes can be

calculated after the data have all been collected. If measurements are entered directly into a spreadsheet program, you can set up the spreadsheet software to perform the calculations automatically.

Table 6.4

Sample Descriptive and Inference Data Table

Day #	Date	Qualitative Description	Inference (What This May Mean)
1	Mon. 10/7	Leaf is dark green in the center, but edges are crispy and beginning to turn brown.	This is the first change I've noticed. The edges may indicate that the over-watering is affecting the plant.
2	Tues. 10/8	Dark brown edges are more noticable and have grown toward the center of the leaf.	As more of the leaf turns brown, less of the surface area can be used for photosynthesis.

It is important to monitor and record the influence of external variables. This can be done by taking measurements and by writing descriptions. These measurements and descriptions should be recorded in a separate data table. For example, temperature, humidity, pH, evaporation rate, and respiratory rate, as well as other influences such as light or radiation, can influence the

Table 6.5

Sample Quantitative and Total Change Data Table

Day #	Date	Plant #1: Leaf Length	Plant #1: Leaf Width	Plant #2: Leaf Length	Plant #2: Leaf Width	Plant #3: Leaf Length	Plant #3: Leaf Width
1	Mon. 10/7	75	15	61	22	89	18
2	Tues. 10/8	77	15	61	22	89	18
10	Thurs. 10/16	82	18	59	25	93	18
Total changes		7 mm	3 mm	−2 mm	3 mm	5 mm	0 mm

Notice that when growth decreases rather than increases the number is negative.

When no change at all has occurred, a zero is recorded.

outcome of the experiment if they are not maintained for all groups within the experiment. External influences vary for each experimental project, but Table 6.6 shows an example of how data could be organized. This data table has columns for experimental day, date, specific measurements, and then a column for descriptive influences.

Table 6.6

Sample Influence of External Variables Data Table

Day #	Date	Room Temperature	Descriptive Influences
1	Mon. Oct. 7	22°C	— —
2	Tues. Oct. 8	19°C	The lights were off when I came in to take measurements today. This may be why the temperature of the room was lower than yesterday.
3	Wed. Oct. 9	21°C	— —

Documenting Evidence Using Photographs

In addition to writing descriptions and recording numbers in data tables, you should consider taking photographs of your experiment. Photographs are an excellent way to document things like the experimental setup and the entities being studied for data collection. Your teacher may even require you to add photographs to your final paper; they also make great additions to posters if your final project is going to be presented at a poster symposium or science fair. Consider taking the following photographs:

- You, the researcher, shown working on your experiment
- Experimental setup, to show the overall environment
- Individual photos of the experimental and control groups on the first and last day of the experiment (and maybe additional photos throughout)
- Close-ups of how data were collected—for example: a close-up photograph of your hands holding the instrument to take measurements.

Be sure that it is easy to determine important information about each photo. Consider labeling each entity with labels or index cards marked

with the date or how long the experiment has progressed, such as shown in Figure 6.1. Be sure to write in dark permanent marker or a thick font so it will show up in the photographs. Or add these labels later using photo editing programs.

Figure 6.1

Photography Cards

Control Group pH 5.5 Day 7	Experimental Group #3 pH 6.0 Day 7

Consider these tips for taking good photos:

- If you put more than one entity in a photo, place each entity in the same order every time you photograph the entities. That will make it easier to discuss the differences when you begin analyzing the results.
- Determine the prime spot to take photographs. Take photographs with the same background every time. If you can use natural light instead of flash, do it.
- Be careful not to take photos facing straight into windows or mirrors or you will get a bad reflection.
- Get as close as you can to your entity when photographing it. Many cameras have a "macro" setting that allows you to get within centimeters of your subject and still remain in focus. The symbol is usually a tulip-shaped flower.

Photographs that capture the experimental setup and entities throughout the experiment belong in the laboratory notebook. Place setup photos in the Record of Procedure section; photos of the entities belong in the Data Table section. *Be sure to date, accurately label, and describe each photograph.*

Use Technology to Organize, Share, and Protect Photographs

There are many ways to use technology to help organize, share, and protect the photos you have taken throughout your experiment. Consider storing your photos online. Photography-sharing sites, such as Flickr, have annotating features, which allow you to highlight portions of the photos to tag. You could add quantitative measurements and/or descriptive notes about each

entity right "on" the photo. This leaves a box on the photograph, and when hovered over, a pop-up window displays the text.

But photography is not your only option. Consider making short videos during the research project. Record how you collected data, along with the results. Edit these videos into short digital stories and post the videos to a class or individual blog. Or post them to a video-sharing website such as YouTube, TeacherTube, or Google Videos.

If your laboratory notebook is organized online, you should directly put the photographs in the appropriate sections or provide links to where they are. For example, on your Data Tables page, in addition to links to your online data tables, you could include links to Flickr. Each photograph must be dated, accurately labeled, and described.

Graphs, Statistical Analysis, and Conclusions

The last section heading of your laboratory notebook is Graphs, Statistical Analysis, and Conclusions. You will use this section after the experiment is complete. This section is the place for you to begin to statistically determine whether or not your hypothesis was supported. You will reorganize your raw data into tables and graphs to show comparisons and calculate statistical tests to determine significance of your results. All graphs, statistical tests, and calculations, whether completed longhand or using technology, should be inserted (clearly labeled) in this section. If you use technology, be sure to *print out results* and paste them in your notebook, even if you don't think you'll use this information in your final paper. Next to the calculations and graphs, record your thoughts about what they may indicate about your experiment. More specific instructions for analyzing your data and recording these ideas into the laboratory notebook are in Chapters 7, 8, and 9.

Conclusions

Keeping accurate, honest, and reliable records is critical to the research process. On the days that you are collecting data, you should be writing in more than one place in your laboratory notebook. For example, you are likely to be writing in

- Record of Procedures (to account for what you completed that day, maybe inserting photographs taken)
- Data Tables
    - Quantitative data tables for each entity
    - Qualitative (descriptive) and inference data table
    - Influence of external variables data table

Chapter Questions

1. Why is it important to keep an accurate laboratory notebook?
2. What are the pros and cons of paper laboratory notebooks? What are the pros and cons of online laboratory notebooks?

Chapter Applications

Decide whether you want to organize a paper or online laboratory notebook, and begin construction. The more time you put into organizing it now, before you begin your experiment, the less hassle you will have once you begin collecting data. Tailor the ideas in this chapter to fit your own experimental design. The sample data tables provided in this chapter are just that—samples. The primary goal is to organize your data so that they are ready for statistical analysis later. The ways you might choose to record the data are less important than the fact that they are organized and all in one place.

Once your teacher has given you the offical experimental start date, you may begin your experiment. The key now is to actually do what you have said you would do in your proposal. If you run into issues you did not anticipate, especially if you are considering varying from the methods you proposed, talk to your teacher. After you have received approval to make changes, record this approval in the Record of Correspondence section of your notebook and move forward. The next three chapters will help you as you begin to organize and analyze your data for analysis.

If working with others on your STEM research project, assign roles to each group member and write a contract agreement for all members to sign. Then turn the document in to your teacher (see also p. 80).

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