Doing Experiments

If you are using a scientific hypothesis or theory to make predictions, you will have to test those predictions to see if they are true. While you can sometimes test your predictions by just making more observations of the world around you, a scientist generally tests hypotheses or theories by doing experiments. You will be doing a lot of experiments in this course, so I want to take you through an experiment, detailing how you should approach the experiments you will be doing.

The first thing you need to realize is that you are not doing experiments to confirm the predictions of a hypothesis or theory. Instead, you are doing them because I think you can learn something valuable by doing them. Thus, you will not be making hypotheses and testing hypotheses in this science course. If you become a scientist, you will be doing those things. For now, you are doing experiments so that you can learn things.

As a result, your main goals for an experiment are to follow the directions, make notes that will allow you to remember what you did in the experiment, and write about the experiment so that you will understand what I want you to learn. Below, you will find instructions for your first experiment. Collect the supplies that are listed and follow the directions. Some of the directions are in italics. Don't worry about that right now. You will learn what the italics mean later. Just follow those directions like you follow all the other directions.

Experiment 1.1: Getting the "M's" off M&M's

Supplies:

- Some plain (not peanut) M&M candies (You need at least 12 candies.)
- Water
- Vegetable oil
- Two small glasses, like juice glasses
- A fork
- *A notebook in which you can keep a record of all your experiments (I discussed this in the introduction to the book.)*
- *A pen or pencil with which to write*

Instructions:

1. *Open the notebook and label the first page "Experiment 1.1: Getting the "M*'s" off M&M's.
2. *Under that label, write "Data:"*
3. Fill one of the glasses about halfway with water.
4. Fill the other glass about halfway with vegetable oil.
5. Put at least six candies in each glass. You can put in more if you want, but you don't want them stacked on top of each other.
6. Use the fork to arrange the candies so that they form a single layer at the bottom of the glass, and the m's on the candies are all facing up so that you can read them.
7. Watch both glasses for about a minute.
8. *Underneath the word "Data:," write the following in your notebook: "After the candies were arranged in the water," and then describe what you see in the glass that contains the water and the candies. Have the candies changed at all? Has the water changed at all?*

9. *Underneath what you just wrote, write the following in your notebook: "After the candies were arranged in the oil," and then describe what you see in the glass that contains the oil and the candies. Have the candies changed at all? Has the oil changed at all?*
10. Let the experiment sit for fifteen minutes. To be most efficient, do some other schoolwork during those fifteen minutes. Don't just waste them.
11. After fifteen minutes, examine the glasses again.
12. *Underneath what you have written so far, write the following in your notebook: "After the candies had been in the water for about fifteen minutes," and then describe what you see. Be very specific. You should see some things floating on the surface of the water. What do these things look like? How does this compare to what you wrote after they had been in the water for just one minute?*
13. *Underneath what you have written so far, write the following in your notebook: "After the candies had been in the oil for about fifteen minutes," and then describe what you see. Be very specific. Most importantly, describe the differences between what you see in this glass and what you see in the other glass.*
14. If you want, try to pick up some of what is floating in the water. The best way to do that is to put your finger under what is floating and then lift your finger up so that it sticks to your finger.
15. *If you did that, write down what you saw underneath what you have already written.*
16. Clean up your mess. You can pour everything down the drain. Use dish soap and water to clean out the glass that had vegetable oil in it.

Tomorrow, I will talk about why I had you do the experiment and the rest of what you need to do to properly record your experiment. For right now, I just want to explain the results to you. When you put the M&M's in water, the candy coating began to dissolve in the water. That's why colors started to spread out into the water from the candy. However, M&M's are also covered with a layer of edible paper, and the "m" that you see on each candy is on that paper.

Well, paper doesn't dissolve in water, so as the candy coating dissolved, the paper did not. Eventually, it had nothing to cling to anymore, so it detached from the candy and floated to the top of the water. As a result, you saw little bits of paper floating on top of the water. You actually eat that paper when you eat an M&M candy. You don't taste it because it is very thin, but you do eat it. It's possible that the "m" actually stayed together as the paper left the candy, so you might have seen little m's floating on the water.

But what happened with the vegetable oil? Nothing. That's because the candy coating can't dissolve in vegetable oil. As a result, nothing changed. No colors spread out from the candies, and no paper floated to the top. That actually points to a very important difference between oil and water. You will learn about that later on in this course.

Documenting Experiments

You just did an experiment that taught you about M&M's candies. You found out that they are covered in edible paper, and the "m" that you see on each candy is on that paper. Of course, I could have just told you that fact, but doing the experiment not only allowed you to *see* the paper, but it also allowed you to learn a few other things. For example, you learned that the candy coating dissolves in water, but not in vegetable oil. You also learned that while the candy coating dissolves in water, the edible paper does not.

The problem with learning things is that you can forget them pretty easily. As a result, it is important to document what you learn. That way, you can always go back later and review the

material. When it comes to documenting what you learned by reading this book, you answer questions and take tests. How do you document what you learned in an experiment? By recording important aspects of the experiment in your laboratory notebook.

If you go back and look at the directions I gave you in the experiment, the italicized instructions all had to do with the notebook. I told you to label the page in your notebook with the number and title of the experiment. Then I told you to write "Data:" underneath the title. That's how you should start to document every lab you do. You should write the experiment number and its title. Underneath, you should write "Data:" to indicate that what follows will be all the data you collect from the experiment.

What are the data you collect in an experiment? Notice what I told you to write underneath "Data:". I told you to write what you saw happening in the experiment. Those are your *observations*. Every experiment has data, because every experiment requires you to make observations as the experiment progresses. So under "Data:" you should list every observation you make. Each new observation should be written underneath the previously-made observation. Some experiments require more than just observations. Some require measurements. If the experiment instructions tell you to measure how long something is, that measurement is also considered data and should be written down along with your observations.

Also, notice that each piece of data needs to have a short explanation regarding when you collected it in the experiment. The instructions told you to write, "After the candies were all arranged in the water" followed by what you saw. That allows you to remember what you did right before you made the observation. It doesn't need to be a long explanation. It just needs to be a short note that will help remind you of what was done right before the observation was made.

The data section of each lab report, then, contains the quick notes you make while you are doing the experiment. They help remind you what you saw at each important step in the experiment. You write these things down while you are doing the lab so that they are fresh in your mind.

Now the reason I wrote the notebook-related instructions in italics is because I don't need to give you those instructions ever again. You should do those things automatically every time you do a lab. Before you start each lab, start a new page in your notebook. Label the page with the experiment number and its title. Then put the word "Data:" beneath the title. After that, write each observation you make along with a note about when that observation was made.

But that's not all you need to do to document your lab. So far, I have discussed things you write down *while you are doing the lab*. Once the lab is over, you need to finish documenting it. How do you do that? You add another section to your lab report that is labeled "Summary:". In that section of the lab, you write your own summary of what you did. It should not be a step-by-step listing of the instructions, and it *cannot* be a copy of the lab instructions that are in the book. Instead, it needs to be your "story" about what you did in the experiment. In the next section, I will show you how I would document the lab, and you can see what I mean.

Once you have finished your summary, there is one more section you need to add. Label this section "Conclusions:", and it should contain a discussion of what you were supposed to learn by doing the experiment. This is actually easy, because I always explain that after the experiment. So all you have to do is give that same explanation, but in your own words. Once you've done that, you are finished documenting your lab.

While this might seem like a lot of work, it's important for three reasons. First, it gives you something you can review later so that you can remember what you learned. Second, when you write something out in your own words, you think through it. As a result, you learn it better. Finally, there are times where you have to actually show evidence that you did experiments. Most universities, for example, require that students do experiments as a part of their high-school science courses. If you apply to a university, the people who decide whether or not you can come to the university might ask you to demonstrate that you did experiments. A lab notebook is exactly what they are looking for.

How to Document the Previous Experiment

Now that I have described the process of lab documentation in general, here is an example of how I would document the lab that you just did:

Chapter 1: Getting the "M's" off M&M's

Data:

After the candies were arranged in the water, the colors started spreading away from the candies into the water. The colors stayed near the candies. They did not rise to the top of the water.

After the candies were arranged in the oil, nothing seemed to happen. The candies and oil did not change in any noticeable way.

After the candies had been in the water for about fifteen minutes, the candies were mostly dark, and the colors had mixed together in the water. There were bits of paper floating on the surface of the water, and some of them had the letter "m" on them!

After the candies had been in the oil for about fifteen minutes, they looked the same as before. Neither the candies nor the oil changed. That is very different from the candies in the water.

I tried to pick up an "m" with my finger. It took a couple of attempts, but it eventually stuck to my skin. It looked like the "m" had been printed right on my finger!

Summary:

In this experiment, I filled one small glass halfway with water and another small glass halfway with vegetable oil. I then added six M&M candies to each glass and used a fork to arrange them in a single layer so that the m's on each candy were facing up. That way, I could see them. I observed them right after they were arranged, and then I observed them fifteen minutes later.

After that, I tried to pick up one of the floating m's by putting my finger under it and then lifting my finger up out of the water. I eventually succeeded.

Conclusion:

This experiment showed that the candy coating on M&M's dissolves in water but not in vegetable oil. It also shows that there is paper covering the candy, and that paper doesn't dissolve in water. Instead, it floats to the top. The m's that you see on the candy are on the paper, not the candy coating.

Notice first the structure of my report. I start with the experiment number and title, and then I have a section of data. The data tell the reader what I saw in each stage of the experiment. Then there is a summary, which tells the reader what I did. I didn't just copy the instructions. It's actually a very bad thing to copy someone else's work. Instead, as the word "summary" suggests, I summarized the instructions in my own words. Then, at the end, I have a conclusion section, which tells the reader what I was supposed to learn in the experiment. Once again, I didn't copy what was in the book. I used different words to indicate what I was told the experiment meant.

Now remember, the main goal for doing this is so that you can go back and review it later to recall what you did, what you saw, and what you learned. However, it is also possible that you will need to use this report to give evidence that you did laboratory work in your science course. Since that's one of the goals, you need to write your report so that someone who has never seen the book can understand what you did and what you learned. Obviously, just reading the data section will be confusing to someone who doesn't have access to the instructions, but that's why you add a summary after the data. It helps someone who has not read the book to understand what you did, what you saw, and what you learned.

This is the only example lab report that I will give you in the book. However, if you go to the course website, which is discussed in the introduction to this book, you will find sample lab reports for all the labs in Chapter 2. That should give you some more guidance. For right now, finish your lab report by making a summary and conclusion section that is similar to mine.

Lab Reports in Other Science Courses

Now please understand that there is no standard among science courses regarding how you should document your labs. Some high school science courses require you to write at least a few of your experiments the way you would write about them in a scientific journal. This is usually called a "formal laboratory report."

I don't think students in middle school and high school should do those kinds of reports. First, most students who take science will never actually write such a report in real life. As a result, it seems like a waste of time for most students. More importantly, the way you write a formal lab report changes depending on the kind of science you are doing. As a nuclear chemist, for example, the papers that I have published in the scientific literature follow a completely different format than the papers my wife (a biophysicist) has published in the scientific literature. In my opinion, you should determine what kind of science you will be doing before you start worrying about writing a formal laboratory report.

Other science courses want you to follow the scientific method when you document your lab work. They want you to start your report with a hypothesis and end your report with a conclusion about whether or not your hypothesis was confirmed. I don't see that as reasonable for most situations involving students. After all, that's not what you are doing. You aren't making or testing a hypothesis. You are simply following my instructions. Also, when you make a hypothesis, you should design your experiment to address the hypothesis. Making a hypothesis for an already-designed experiment is backwards when it comes to the scientific method.

If you follow my method for documenting your labs, you will practice the most important aspect of laboratory work: making a record of what you did, what you saw, and what you learned. No

matter what kind of science you end up doing, you will have to do that. Thus, by getting experience documenting labs in this way, you will be honing a skill that you will use if you pursue any kind of science.

This is important, since a scientist's laboratory notebook can become a legal document. If you discover something new and need to demonstrate that you were the one who discovered it, you can do that with your laboratory notebook. In addition, if someone disputes what you have concluded based on your experiments, your laboratory notebook can be used to resolve that dispute. In the end, then, getting used to properly documenting your experiments is an important part of science education.