Lesson 4.1: Lab Write-Ups

Introduction

This document is Lesson 4-1 of the SEAChem2020 open source chemistry curriculum program for secular homeschoolers. This version was current as of 8/30/2017. To if there is a more current version of this document, visit www.SEAChem2020.org.

Table of Contents:

How to use this material:

During the course of this lesson, your child should:

- Read the material in the text and rewrite it in their own words.
- Complete the practice sheet, then write their own, complete with answer key.
- Complete the lab activity, then write their own, complete with suggestions on how to best perform the lab.
- Take the assessment to ensure they understand the material, then write their own, along with solutions.

These steps should be followed by a debrief, in which you and your child will discuss the lesson. Please send us your suggestions, as well as any materials your child writes (text, practice, lab, assessment) so that we may incorporate it into the curriculum.[1]

We welcome any help you are willing to provide in supporting this project. Even if you're not a chemist or a professional educator, you can help in the following ways:

- **Let us know about minor fixes**. If you find anything from a factual to a stylistic error, or even a typo, let us know by using this form.
- **Let us know if you find big problems**. Does something need rewriting? Let us know by contacting us using this form.
- **Give us your resources**. If you've done one of these lessons and have put something cool together, email us at misterguch@chemfiesta.com so we can include it!
- **Volunteer**. Do you want to edit this curriculum? Do you have things to add? Would you like to write some of these lessons? Let us know!
- **Publicity**. Tell your friends about these resources. When the community grows, the project keeps growing!

Thank you for using this resource, and please consider helping out!

1 *Any submitted material added to the curriculum will be licensed under the same Creative Commons license as the rest of this material and will be free for others to use and adapt. Please make sure your name is included somewhere on the submitted resource(s) if you wish to receive credit for your work. All submitted resources may be edited for accuracy, formatting, and style.*

Lesson 4.1: Lab Write-Ups

In Lesson 4, we discussed how to set up a good experiment and carry it out safely. In this lesson, which is an extension of Lesson 4, we'll discuss how to write a good lab using what we've already learned.

What is a lab write-up?

Lab write-ups provide a record of the experiments that you've conducted. They outline the reasons for carrying out the experiments, the hypothesis you tested, the materials and procedure you used, the data collected, and an analysis of what you did. Researchers at all levels keep extensive records of their work in lab books; in turn, these books are treated as the definitive documentation of their experiments and data.

The idea that extensive documentation is required when performing scientific activities is exemplified by the common saying "If you didn't write it down, it didn't happen." Scientists are very serious about making sure that their experimental results are correct and use their lab books as the primary source for their work. If something isn't included in a lab book, other scientists will consider the data to be completely unreliable.

Catching dishonest scientists

Sometimes, scientists publish data with either inappropriately manipulated data or with completely made-up data. When this occurs, those investigating the misconduct review the experimental records to ensure that the data recorded were actually collected and represented correctly. If the records contradict published papers, or if there are no records at all, it can be assumed that scientific misconduct has taken place.

Dr. Yoshitaka Fujii, an anaesthesiology researcher, was found to have falsified data in 182 papers in the 1990's and 2000's.[2,3]

The sections of a good lab write-up

When performing a lab, it's important to include a complete record of everything you do to ensure that you can reliably figure out what you did in the experiment and what data you collected. Without such a record, important information can be lost or misinterpreted.[4] The following pages show what a good lab write-up should look like:

2 *You may find this statement from the Editor-in-Chief of Anaesthesia and Analgesia regarding some of his falsifications interesting: http://publicationethics.org/files/u7140/FujiiStatementOfConcern.pdf.*

3 https://alchetron.com/Yoshitaka-Fujii-553236-W

4 *Depending on your source, there can be many different ways to formalize the contents of your lab write-up. There may be different formalisms involved in this method than in others, but the basic concept when performing any lab write-up is identical: Make a complete record of everything you do.*

Ian Guch
August 16, 2017

An explanation of how to write a good lab

Purpose: To teach the readers of this lesson how to write a lab correctly.

- [An aside: The purpose should always be a single sentence that gives a general idea of what the lab is trying to accomplish. The goal of the purpose is not to indicate every possible thing that might happen – only to show the main point of the lab.]

Hypothesis: If I give a clear explanation of how to write up a lab, then the readers will learn the material.

- [An aside: The hypothesis should always be a single "If, then" statement with the format "If [independent variable – the variable that's manipulated during the experiment], then [dependent variable – the desired outcome]" in order to make it extremely clear what we're changing and what we think will happen. Good hypotheses should include something that can be tested and something that's focused enough that this single experiment can demonstrate it. For example, a hypothesis such as "If I write some stuff, then the reader will do science" is neither testable nor focused enough to be meaningful.

Materials: My home computer, an Internet connection, a web server.

- [An aside: The materials should be both complete and specific enough that the reader could, if he/she chose, reproduce what was done. If three 250 mL beakers were used in an experiment, it would make sense to say "3-250 mL beakers" in the materials list. It is, however, possible to get too carried away with the materials section – though it wouldn't be technically incorrect to say that I was using a home computer with an i3 processor running Lubuntu 16.04, it's also irrelevant to the experiment.

Procedure:

- On my computer, write out an outline of what I want to say about lab write-ups.
- Write this lesson, using the Internet to find interesting little tidbits to add into sideboxes.
- Post the lesson on the SEAChem2020.org website.
- Encourage everybody to contact me online (misterguch@chemfiesta.com) to let me know whether they learned how to write a good lab.
- If suggestions have been made, make changes to incorporate them.

- [An aside: Though it's important to include all of the major steps that you followed when performing your lab, it's also possible to go overboard. For example, I didn't describe how to turn on my computer or how to upload this file onto the Internet. Whenever you write a procedure, assume that the reader will understand the basics of experimental science.]
- [Another aside: It's entirely possible that during the course of your experiment you'll realize that you forgot to write down a step or that you'll decide that you don't want to do something after all. If this is the case, it's absolutely fine if you write in changes to your procedure to reflect what you've done. If this leaves your paper a little messy, that's fine – after all, this isn't a calligraphy contest!]

Data:

Table: What people thought of this lesson

It kind of sucked	It was OK	It was amazing!
5	9	497

When I emailed back the people who said the lab sucked, they usually just told me to get lost. People who said the lab was OK ignored my emails, and people who said it was amazing asked if they could wash my car.

[An aside: The data above give a good idea of the kind of data you want to record. All experiments will require qualitative data, which is non-numerical data (in this case, the comments about how people want to wash my car). Most experiments will also require quantitative data, which is numerical, measured data (in this case, the table). The specific way in which the data are collected will depend on the type of data and when they are collected. Because of this, it's not uncommon for the data section of a lab notebook to get a little messy.]

Results:

Analyzing the data from this experiment, I found that 0.978% of the readers of this lesson thought it sucked, 1.76% thought it was OK, and 97.3% thought it was amazing. Given this information, it's clear that the initial response to this lesson was overwhelmingly positive.

When I contacted the readers later, I found that their opinions of the lesson had not changed. People who thought the lesson sucked showed a strong dislike for me, while those who thought it was OK ignored me and those who loved the lesson wanted to do nice things for me.

Overall, it seems that this lesson was successful and taught the intended lesson to the majority of readers.

[An aside: The results section of the lab is where you discuss the data and figure out what it means. If you've got mathematical calculations to make, this is where you do them. If you need to graph your data, this is the place. This section is where you go through the steps to see whether your hypothesis was supported or disproved.]

<u>Conclusion</u>: When I gave a clear explanation of how to write up a lab, then the readers learned the material.

- [An aside: The conclusion of a lab is a one-sentence statement that mirrors the original hypothesis with its independent and dependent variables. There should not be other stuff written in the conclusion to explain this statement because all of that was already discussed in the results section of the lab.]

<u>Error analysis</u>: Sources of error for this lab include the following

- After I wrote this lesson, my cat deleted it from my computer. As a result, I had to rewrite everything in a more hurried way than I would have liked.
- The example I gave of a lab write-up was written in some stupid novelty font, making it hard to read. Next time, I'd use a more standard font.
- When emailing people, I accidentally sent some of the emails from a different account. As a result, some of the people who received emails got it from "misterguch@chemfiesta.com" email and others got it from "sales@PenIsland.net" This may have caused some of the people I contacted to have a different opinion of me. Next time, I'll make sure to use the same email address.
- [An aside: You should always include at least two sources of error in this section. It's important to realize that you *always* make mistakes when doing experimental work. Some of these mistakes are big and some are small, but it's inevitable that you'll get something wrong. This isn't a mark of incompetence – the reason we point out our errors is so that we can avoid making them again in the future.]

Graphing

Going into this section, I will assume that you understand how to make a basic graph. X-axis, y-axis, there's a line, etc. You probably learned it during some long-ago math or science lesson and feel comfortable with it.

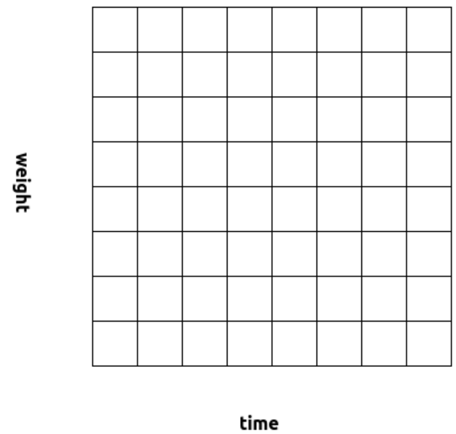
Unfortunately, you probably don't know how to make a good *scientific* graph. Though the basic principles behind making a scientific graph are the same as the ones you are already familiar with, scientists have particular ways in which they prefer to see data presented. We'll practice this in a minute.

For this exercise, we'll make a graph to show how my (the author of this lesson) weight has changed over time. The raw data:

2010: 99 kg
2011: 104 kg
2012: 107 kg
2013: 109 kg
2014: 109 kg
2015: 99 kg
2016: 93 kg
2017: 99 kg

1) The independent variable is on the x-axis (horizontal axis) and the dependent variable is on the y-axis (vertical axis).

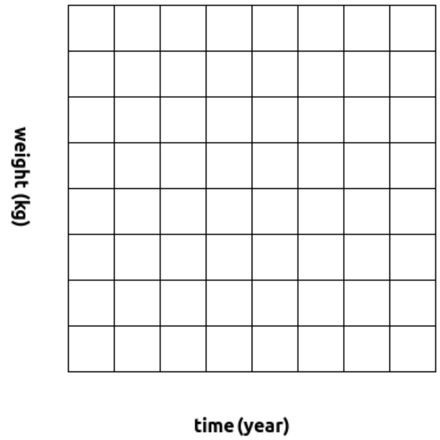
In this case, we have two variables, the year and my mass. To figure out which is the independent variable and which is the dependent variable, we have to ask ourselves which variable changes as the result of the other. Does my weight change over time, or does time change when my weight changes? Because my weight changes when time changes, and I don't go forward or backwards in time when my weight changes, we can assume that time belongs on the x-axis and weight belongs on the y-axis.[5]



5 *Good rule of thumb: Since we haven't yet built a time machine, time will always be graphed on the x-axis.*

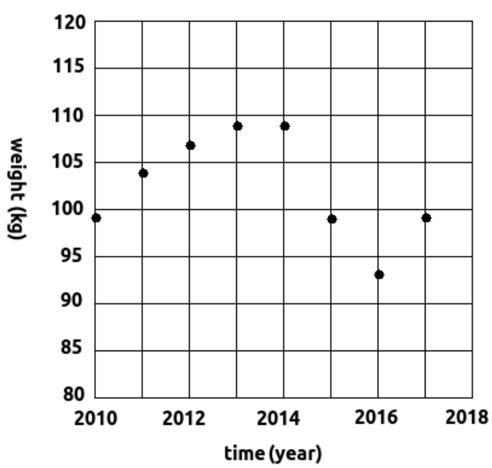
2) Label the units for each axis of the graph.

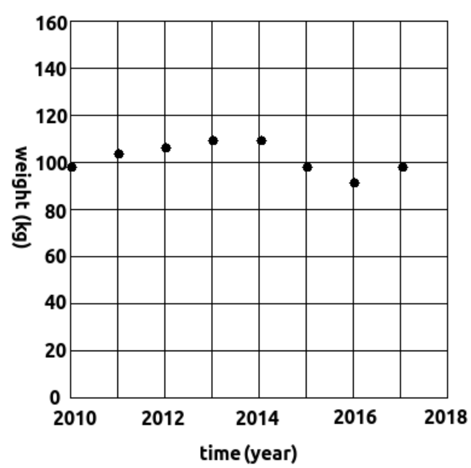
Doing this provides context for the information in this graph. If my weight were to fluctuate like this over a time scale of weeks, this would suggest extremely drastic physiological changes. Likewise, if my weight fluctuated only a few grams over this time scale, this graph wouldn't be particularly interesting.



3) Make sure the units are placed on each axis such that all of the relevant data are represented correctly.

Let's go ahead and make a preliminary graph for these data. In fact, let's make two of them:

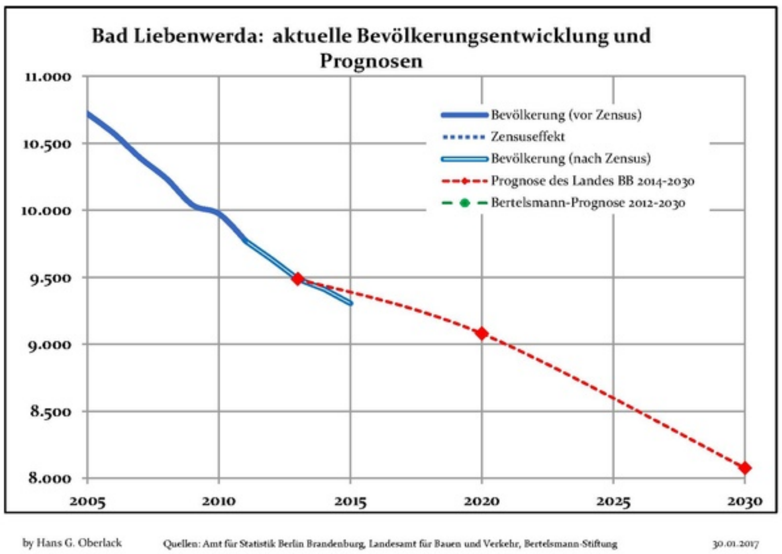




The graph on the left seems like it would be a better choice, as the points are pretty well spread out and give us a good idea of precisely what each value is. However, the graph on the left tells that story that my weight rose drastically between 2010 and 2014, and then dropped drastically between 2014 and 2017. If you look at the graph, it looks like I lost about half of my weight in the past three years! Though it's true I have lost weight, it's misleading to make it look like I'm half as big as I was three years ago.

The graph on the right is actually a better choice. Though the rise and fall of my weight isn't as drastic, it gives the viewer a better idea of the actual magnitude of my weight changes. Though the graph shows that I've lost a lot of weight, it also shows that most of my weight stayed right where it was, which is what we actually observed.

Bad graph scaling is one of the common ways that people can use data to mislead readers about the meaning of data. For example, let's take a look at a graph pulled off of Wikimedia Commons more or less at random:



Even if you don't read German, you can tell from the graph that something very bad is happening here. In fact, it's clear that something that was happening in 2005 will be almost 100% completely stopped in 2030. Of course, if you look at the scale on the left, you can see that the value of whatever is being measured will change from 10.700 to 8.100 over this time scale. Sure, it's a decrease, but it's certainly not the dire picture that this graph suggests.[6]

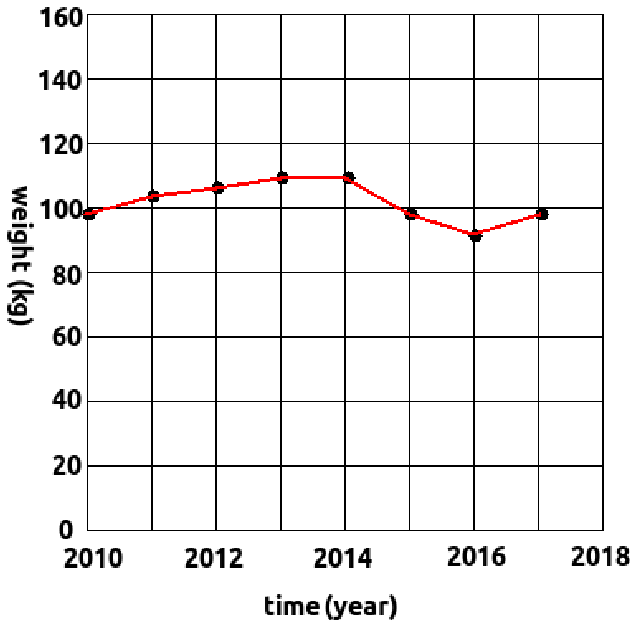
4) Make it a line graph.

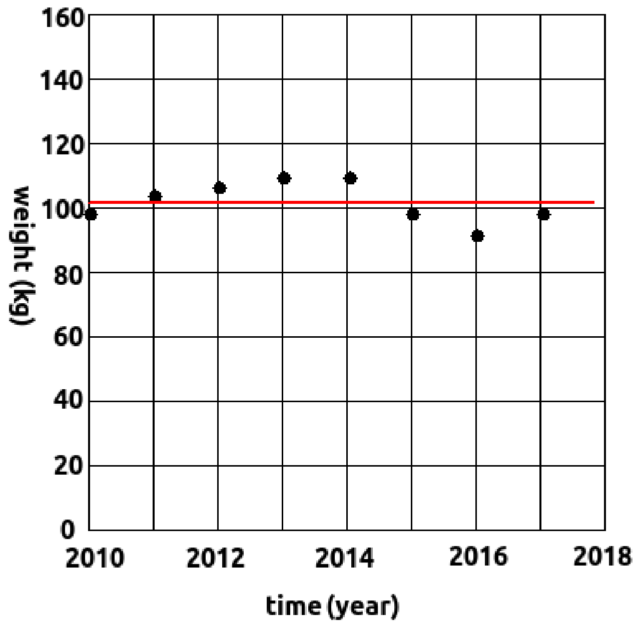
Line graphs show the dynamic relationship of one variable to another. While other forms of graphs (bar graphs, pie charts, etc.) have their uses, they are generally poorly-suited to the sciences.

5) Draw best-fit lines or curves. Never connect the dots.

The biggest mistake that we can make in graphing is to connect the dots rather than drawing best-fit lines. Let's use the example of my weight to see why:

6 *By Hans G. Oberlack [CC BY-SA 3.0], via Wikimedia Commons. This graph is actually an estimate of the population of the town of Bad Liebenwerda. If you're wondering how you can have 10.700 people living in a town, don't be alarmed – in most European countries, commas and decimal points are reversed. As a result, the number 10.700 on this German chart stands for a population of 10,700 in the English-speaking world. For more information about the town of Bad Liebenwerda, visit http://www.bad-liebenwerda.de/.*





The graph on the left is a typical connect-the-dots line graph. Though a typical way to write a graph, it treats each datum as completely, 100% reliable and perfect. There's no way that we could possibly be wrong, and the data are all without flaw. Additionally, from the data shown here it's next to impossible to make a prediction about what my weight will be in 2018.

The graph on the right, on the other hand, shows more correctly that the overall trend for my weight change is flat. Though I've lost a considerable amount of weight from my peak, my current weight is in line with my general, lifetime weight. we can predict that in 2018, my weight will probably be around 100 kg, give or take.[7]

6) The appropriate title for a scientific graph is "The effect of [independent variable] on [dependent variable]", or "The dependence of [dependent variable] on [independent variable]." (they both mean the same thing)

When titled correctly, this graph should be called "The effect of the year on my weight" or "The dependence of my weight on the year." Personally, the second one sounds better, but they both mean the same thing.

7 *If warranted, a best-fit curved line can be used when drawing graphs. However, it's important that when doing this, the person making the graph not just connect the dots!*

The main ideas in this lesson:

- Lab write-ups are important because they are our primary record of what we have done in the lab.
- A good lab write-up is complete and contains purpose, hypothesis, materials, procedure, data, results, conclusion, and error-analysis sections.
- It is important to make graphs in the correct format to ensure that readers easily and unambiguously understand the information being conveyed.

Lesson 4-1 glossary:

conclusion: A one-sentence statement mirroring the hypothesis that either expresses it as a positive or negative statement. For example, if the hypothesis being tested was “If I flap my arms quickly, then I will fly,” the likely conclusion will be “When I flapped my arms quickly, I did not fly.”

data: The information collected when an experiment is run. This may consist of qualitative data (non-numerical data) and quantitative data (numerical measurements).

error analysis: The second of a lab in which all reasonable sources of error are explored. There are *always* sources of error in a lab – to suggest otherwise implies that the experimenter and experimental apparatus are both infallible. It is important to remember that reasonable sources of error may differ from one experiment to another. For example, it is unlikely that “seismic activity” will be a reasonable source of error, except in the unusual case where an earthquake caused experimental data to be compromised.

hypothesis: “An if [independent variable], then [dependent variable]” statement that predicts the relationship between the independent variable (the variable being manipulated by the experimenter) and the dependent variable (the outcome of this manipulation). The hypothesis in a lab write-up should only contain this one statement.

line graph: A graph that presents the data as a trend line. This is always preferable to other forms of graphs when presenting the results of scientific data. (Note: Other types of graphs such as bar graphs, pie charts, etc. have their uses elsewhere, but not in representing experimental data).

materials: The section of a lab write-up that lists all of the materials required to perform the lab. The materials list should be complete and specific, with descriptions of each item used when appropriate.

procedure: The section of a lab write-up that describes each of the steps that were undertaken during the experiment. The procedure is meant to be a record of what happened and should be written with enough specificity that a reasonable person could reproduce your experiment. Writing the procedure as a bulleted list of instructions is usually fine.

purpose: The reason you have for doing a lab experiment. The purpose in a lab write-up should contain one sentence that sums up the main reason the experiment is important.

qualitative data: Observations from an experiment that are non-numerical in nature. “The solution turned blue” is an example of qualitative data.

quantitative data: Measurements from an experiment that involve numbers. “6.5 grams of lithium acetate was formed” is an example of quantitative data.

results: The section where the data are analyzed to determine whether the hypothesis was supported or disproved. A good results section should outline the reasoning that went into analyzing these results, as well as include any graphs or calculations that assist this analysis.

x-axis: The horizontal axis on a graph, indicating the independent variable. If time is a variable, it is *always* shown on the x-axis.

y-axis: The vertical axis on a graph, indicating the dependent variable.

Lesson 4-1 Practice Sheet

Writing a Proper Lab

Imagine that you've got the following problem: Every time you try to go to sleep, a neighborhood cat outside of your window starts howling and keeps you up. Devise an experiment that tests some way of stopping this problem so you can get some sleep. For the data/results/conclusion/error analysis sections, use your imagination to guess what *might* happen during your experiment!

Purpose:

Hypothesis:

Materials:

Procedure:

Data:

Results:

Conclusion:

Error analysis:

Lesson 4-1 Practice Sheet Answers

Writing a Proper Lab

Imagine that you've got the following problem: Every time you try to go to sleep, a neighborhood cat outside of your window starts howling and keeps you up. Devise an experiment that tests some way of stopping this problem so you can get some sleep. For the data/results/conclusion/error analysis sections, use your imagination to guess what *might* happen during your experiment!

Purpose: To get some sleep.

Hypothesis: If I give the cat some tuna, then it will shut up.

Materials:

- 1 can of tuna
- can opener

Procedure:

- Wait until the cat starts making noise
- Use the can opener to open the can of tuna
- Put the opened can of tuna outside where the cat makes noise

Data:

- The cat stopped making noise for ten minutes
- The cat started making noise four times a night

Results: Based on the observations, I found that the cat stops making noise for ten minutes after feeding, but that the feeding seems to bring the cat around the house more often, resulting in a more difficult sleeping environment.

Conclusion: When I gave the cat some tuna, it did not shut up.

Error analysis:

- I am not certain that the screaming cat is the same one that I fed.
- I do not know if the repeated screaming is all from the same cat.
- It is difficult to determine things precisely when I am very sleepy.

Lesson 4-1 Practice Sheet

Graphing Practice

Graph these data, which show how the weight of an average small child increases over the first year of life:

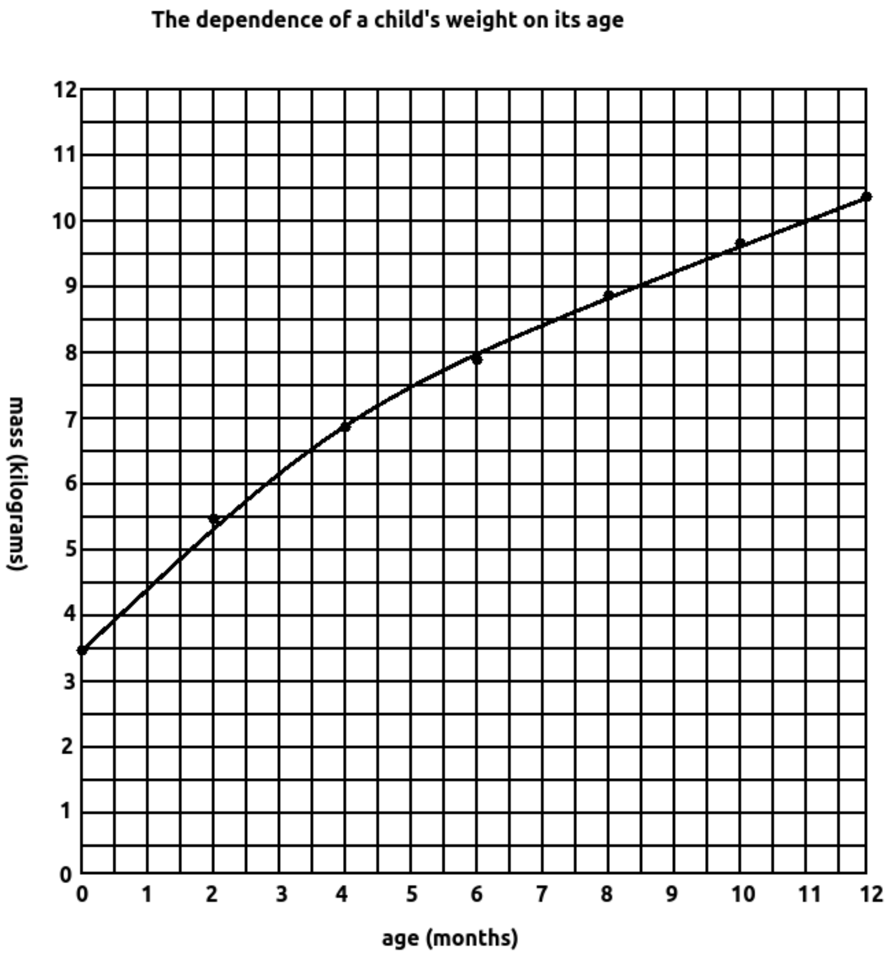
age (months)	weight (kg)
0	3.5
2	5.5
4	6.9
6	7.9
8	8.9
10	9.7
12	10.3

Lesson 4-1 Practice Sheet Answers

Graphing Practice

Graph these data, which show how the weight of an average small child increases over the first year of life:

age (months)	weight (kg)
0	3.5
2	5.5
4	6.9
6	7.9
8	8.9
10	9.7
12	10.3



Note: This graph is best served not by a straight line but by a best-fit line (i.e. a curve that best fits the data). When making a graph, it's important to use your judgment about whether a straight line or curve best represents the data (though a connect-the-dots is *never* the best choice!)

Not Too Much, Not Too Little Lab
Parent guide

In this lab, your child will be combining vinegar (5% acetic acid) with baking soda (sodium bicarbonate) to form carbon dioxide bubbles, water, and sodium acetate (dissolved). You have probably seen this reaction before in “vinegar/baking soda volcanoes”, which foam because of the formation of carbon dioxide gas.

Goal: To teach the proper method for writing up a chemistry lab, as well as to demonstrate that reagents have to be combined in certain ratios in order for reactions to completely occur.

Home destruction factor: 3/10. It's only vinegar and baking soda, but you may note overflows when they're combined, making a somewhat sticky mess.

Time required: 60 minutes (30 minutes experiment, 30 minutes write-up)

Safety: Vinegar is minimally-dangerous, but it's always a good idea to wear goggles!

Materials:
- 1 bottle of 5% vinegar (150 mL is required, so you may already have this at home)
- 1 box of baking soda (10.5 grams is required, so you may already have this at home)
- Three beakers/bottles/containers for performing the reaction

How it works:
Your child has been told to add 50 mL of 5% acetic acid to three different quantities of sodium bicarbonate: 1.0 gram, 3.5 gram, and 6.0 gram. When your child performs this experiment, they should observe the following:
- Reaction 1: Acetic acid + 1.0 g sodium bicarbonate results in some fizzing
- Reaction 2: Acetic acid + 3.5 g sodium bicarbonate results in a great deal more fizzing
- Reaction 3: Acetic acid + 6.0 g sodium bicarbonate results in the same amount of fizzing as it did when it reacted with 3.5 g sodium bicarbonate

The amounts of acetic acid and sodium bicarbonate have been set up to assure the following:
- Reaction 1: The quantity of sodium bicarbonate is not sufficient to cause the acetic acid to completely react.
- Reaction 2: The quantity of sodium bicarbonate has been increased to the point where all of each compound undergoes the reaction.
- Reaction 3: Additional sodium bicarbonate has been added and when the reaction is complete some of the sodium bicarbonate is left over. The reaction is the same size as in Reaction 2 because both reactions have converted the acetic acid to products.

This concept, that certain ratios of reagents will combine with one another in a reaction, is called stoichiometry. We will discuss this at much greater length later in this curriculum. It is included in this lab because it gives an excellent opportunity to practice writing up labs. A sample lab write-up is included on the next page. Your child's lab should be similar to this, though he/she may come up with different conclusions.

Your Child's Name
Today's date

Not too much, not too little lab

Purpose: To figure out what happens when we combine various quantities of baking soda and vinegar.

Hypothesis: When I add vinegar to increasing quantities of baking soda, the reaction will become more intense each time.

Materials:

- 150 mL of 5% acetic acid (household vinegar)
- 10.5 grams of sodium bicarbonate (baking soda)
- Three drinking glasses [or whatever was used]

Procedure:

- I put on goggles.
- In each experiment, I placed some sodium bicarbonate into the cup where the reaction took place. In reaction 1 I used 1.0 grams, in reaction 2 I used 3.5 grams, and in reaction 3 I used 6.0 grams.
- To each cup I added 50 mL of 5% acetic acid.
- I observed the results of the reaction.
- Clean-up: I poured the contents of each beaker down the sink and rinsed the sink with water to remove the residue.

Data:

- Reaction 1: I observed a small amount of bubbling that ended after about 15 seconds.
- Reaction 2: I observed a more vigorous amount of bubbling that continued for about 25 seconds. When the reaction was complete, there were still small bubbles on the side of the cup.
- Reaction 3: I observed a similar amount of bubbles as in reaction 2 for a similar amount of time. When the reaction was complete, there were still small bubbles on the side of the cup. However, unlike reaction 2, the solution remaining was cloudy/milky white.

Results:

- Because only a small amount of bubbling occurred in reaction 1 compared to the other two reactions, I can only conclude that there wasn't enough sodium bicarbonate to finish the reaction. I believe this because the amount of sodium bicarbonate was less than for the other reactions.
- Because the same amount of bubbling occurred in reactions 2 and 3, I would assume that the amount of sodium bicarbonate wasn't the main factor in how vigorous the reaction was. This suggests to me that the acetic acid ran out before the sodium bicarbonate did, causing the reaction to be equally vigorous in both reaction 2 and 3.
- The third reaction was cloudy at the end, which tells me that there was perhaps some sodium bicarbonate left over after the reaction was complete. Because this wasn't present during reaction 2, I believe that reaction 2 had a perfect ratio of acetic acid to sodium bicarbonate, while reaction 3 had too much sodium bicarbonate.

Conclusion: When I added vinegar to increasing amounts of baking soda, the reaction was <u>not</u> more intense each time.

Error analysis: The following errors may have occurred in this lab

- I may not have measured the quantity of each reagent correctly.
- There may have been some error in the measurement of how long the bubbling occurred, because bubbles remained on the side of the cup after the reaction was complete.
- A failure to stir the reagents together may have delayed the reaction, or caused the reaction to occur over an artificially long period of time.
- The vinegar may not have been exactly 5% acetic acid, as this was meant as a food and not a reagent.
- [Other reasonable sources of error].

Not Too Much, Not Too Little

In this lab, your goal is to determine how differing quantities of reagent affect the intensity of a chemical reaction. You will do this by combining the following:

- Reaction 1: 50 mL 5% acetic acid (i.e. vinegar) with 1.0 grams sodium bicarbonate (baking soda)
- Reaction 2: 50 mL 5% acetic acid with 3.5 grams sodium bicarbonate.
- Reaction 3: 50 mL 5% acetic acid with 6.0 grams sodium bicarbonate.

Please devise an experiment with your goal in mind and present it to your instructor as a formal lab write-up with the following elements:

- Purpose: Why you're doing this
- Hypothesis: “If [independent variable], then [dependent variable].”
- Materials: A specific list of everything needed.
- Procedure: A description of the steps that need to be followed to perform the lab.
- Data: Whatever data you have collected, including qualitative data and quantitative data where appropriate.
- Results: An analysis of how your data relates to the hypothesis.
- Conclusion: “When [independent variable], then [dependent variable].”
- Error analysis: At least two sources of error, with suggestions about how they can be minimized in the future.

Good luck!

Lesson 4-1 Assessment

1) Why is it so important that scientists keep good records of their experiments?

2) Why is it vital that experimenters include both qualitative and quantitative data in their lab reports whenever possible?

3) Why shouldn't we connect the dots when drawing a graph?

4) Why is time always on the x-axis of a graph?

Lesson 4-1 Assessment Answers

1) Why is it so important that scientists keep good records of their experiments?
The records that scientists keep in their lab books are the definitive record of what happened during an experiment. If something isn't written down, then there is no evidence that it ever happened and no conclusions can be drawn from the results of this experiment. Additionally, the lab reports that scientists write allow other scientists to reproduce the work that was done in the experiment, which gives them a good way to verify any experimental result.

2) Why is it vital that experimenters include both qualitative and quantitative data in their lab reports whenever possible?
Quantitative data is numerical data, and it's easy to see that you'd want to keep track of how much of a product you form or how long it took for something to happen. Qualitative data, however, can be just as important because it allows experimenters to know what events happened when performing the experiment. This can be useful because it gives experimenters hints on what they should expect when performing the experiment and because it helps them to figure out whether something is working.

3) Why shouldn't we connect the dots when drawing a graph?
Graphs tell us what the general trend of data are. When we draw either a straight line or best-fit curve, we're telling the reader what the data mean in a general sense. However, if we were to connect the dots, we would be telling the reader that each of the data points were perfect, and that there's no uncertainty in what we've done. Since this is clearly not the case, we cannot do this.

4) Why is time always on the x-axis of a graph?
The x-axis is the independent variable, which means that other things (dependent variables) change as a result of changes in the independent variable. When time is one of the variables in an experiment, we always need to have it on the x-axis because other variables change as a function of time, but time never goes forwards or backwards in response to another variable.

Lesson 4-1: References For Further Study

A different description of how to write up a lab:
You'll note that, while it differs in the specifics, all of the same elements are present.

- http://schools.cbe.ab.ca/b631/Science%20Web%20Page/Grade%209%20Science%20Web%20Page_files/9%20How%20To%20Write%20Up%20A%20Lab%20Report.pdf

A description of academic dishonesty in the sciences, focusing on plagiarism.

- https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3558294/

Consequences of academic dishonesty:

- Mt. Airy High School in NC has a pretty standard honor code for cheating. As you can see, this is an issue they take very seriously: http://www.mahsbears.org/apps/pages/index.jsp?uREC_ID=358398&type=d&pREC_ID=775969
- How is the honor code treated at the university level? Here's an overview, with a focus on the famous honor code of the Virginia Military Institute: http://articles.latimes.com/1994-04-03/news/vw-41646_1_honor-code
- In professional publications, dishonesty can destroy one's career. An ongoing set of reports about retracted scientific papers can be found here: http://retractionwatch.com/

A nice description of graphing:

- http://www.cns.nyu.edu/~msl/courses/0044/handouts/GraphingStyle.pdf

Correlation and causality:

- You may think that when two variables change in sync with one another, then you can assume that one causes the other to happen. This leads to the famous saying "correlation does not imply causation", in which it's understood that a third confounding variable may be responsible for the two you've observed. Read more: http://senseaboutscienceusa.org/causation-vs-correlation/
- Another interesting story about correlation and causation: http://www.softschools.com/examples/science/confounding_variable_examples/479/. I'm particularly fond of the murderer/ice cream example.