DIAL "C" FOR COLLABORATION:

FINDING UNKNOWNS WITH YOUR FELLOW SCIENTISTS

Brianna Stanley
Virginia Institute of Marine Science

Grade Level
High School

Subject area
Biology, Chemistry, Mathematics

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Title Dial C for Collaboration: Finding Unknowns with Your Fellow Scientists

Focus Scientific collaboration and how to use knowns to measure an unknown using a linear equation

Grade Level HS Biology, HS Chemistry, Mathematics (8th Grade or Algebra)

VA Science Standards

- BIO.1 c) or CH.1 c) interpreting, analyzing, and evaluating data
- BIO.2 d) constructing and critiquing conclusions and explanations
- A.6 a) determine the slope of a line when given an equation of the line, the graph of the line, or two points on the line;
- 8.16 b) identify the slope and y-intercept of a linear function, given a table of values, a graph, or an equation in y = mx + b form;

Learning Objectives

- Students will apply a data set to create a graph and to answer a question
- Students will use Excel or another graphing software to make a basic graph
- Students will manipulate a linear equation to find an unknown value
- Students will identify who the collaborators are in their own education

Total length of time required for the lesson
90 minutes

Key words, vocabulary
Quality Control – QC, ensuring that the quality of data remains the same as the experiment is repeated
Scientific Collaboration – Scientists working together on a shared project or socially. Scientists can have collaborators that help them in the same lab group, the same school, and at other schools around the world!
Collaborators – people who work together to reach a shared goal. These can be scientists working on an experiment or friends working on a class project together.
Standard Curve – Also called a calibration curve, it is a graph used to solve for an unknown. Standards with known properties or concentrations are measured and graphed, to allow the same properties to be determined for an unknown sample by interpolating the graphed data.
Standards – A set of samples used to collected data for the known data points in a standard curve. These may be prepared by a scientist to have a known/set amount of the compound they want to measure.
Standard Reference Material – A certified standard with a known value that is produced by a trusted source and available to scientists to verify their standards.

Background Information
See additional background in PowerPoint

My name is Brianna Stanley and I am a graduate student at the Virginia Institute of Marine Science studying how nitrogen cycles in coastal waterways. I am interested in studying nitrogen because it is an important nutrient (food) source for phytoplankton. Phytoplankton form the base of the food web and are important members of our ecosystems. Nutrients are often measured in order to monitor the health of local waterways, because they can support phytoplankton and algae growth.

Nutrients are measured as a concentration and this activity uses real standard curve data that was used to measure that amount of ammonium from an experiment in the York River, Virginia! Ammonium is a yummy and important food source for phytoplankton! I kept the concentration/unknown sample a bit vague in the activity sheet, because you could adapt this activity to a scenario other than coastal nutrients! Feel free to use the concepts of graphing and collaboration in this activity to explore other ideas that you've been covering in class! Concentration could substitute for the amount of dye in water, amount of iron in the bloodstream, or almost any other concentration measurement! The important concepts that students should get out of this activity are using knowns to find an unknown, quality control, graphing linear equations, comparing data, and collaboration!

This activity combines science, math, and collaboration by examining the use of standard curves in science. When a scientist wants to measure something unknown (concentration, absorbance, or other properties), they will use a series of known samples to infer the property of their unknown. A standard curve is the term for when the knowns are graphed and then used to interpolate their chosen property. This is used in most fields of science and for most measurements that are made using a scientific instrument. The activity included in this lesson plan uses data from the measurement of the nitrogen nutrient ammonium in seawater. Ammonium concentration is measured based on the absorbance of light (in this lesson plan "reading," which is unitless) and is calculated based on a standard curve prepared by a scientist with several samples of known ammonium concentration (Koroleff, 1983). Students in this lesson plan will get to use real ammonium standard curve concentration and absorbance ("reading") data to practice plotting in Excel. Once they plot and obtain a linear equation for their data, students will have to manipulate the linear equation in order to back calculate the concentration of an ammonium sample that they have a reading for.

In the second part of this activity, students will practice collaboration in order to perform a quality control check of their samples by comparing results with other students. This activity will demonstrate how scientists work together to verify their results. Collaboration requires trust and a shared goal, as well as strong communication skills. Usually, each member brings their own expertise to a larger project (Bennett and Gadlin, 2012). A good example of large-scale scientific collaboration are projects like the International Space Station. However, collaboration can be small and is important in the process to verifying that scientific results are reproducible.

The activity in this lesson plan is an example of quality control, which can easily be confused with quality assurance. Quality assurance are the processes that scientist uses to ensure they produce good data. For example, using an established protocol for measuring ammonium. Quality control is a check to ensure that the data is consistent and comparable, and includes using checks like standard curves and certified standard reference material. In Part 2 of this activity students will be preforming a comparison check for their graphing data from Part 1. If there is time at the end of the class you can cover scientists using standard reference material. Reference material are standards with a known value that are agreed on by multiple scientists and are often purchased from science companies who ensure the quality of the sample. They can then be used as a check if there isn't time to send samples to verify to a collaborator.

Materials & Supplies

- Projector/screen for introductory PowerPoint
- Student access to Microsoft Excel or alternative graphing software
- Worksheets (Appendix 1), 1 group sheet per graphing exercise and 1 per collaboration exercise
- Key (Appendix 2)
- Graphing Tutorial (Appendix 3 for Excel or 4 for Google Sheets)

- Excel graphing sheets or Google Sheet links https://drive.google.com/drive/folders/1yuXu6io8VwSwXKUajQBvhjPZgt55Hqi7?usp=sharing
- Optional: calculator

Teacher Preparation

Students will be working on this activity in two sets of pairs, so ideally the classroom would be arranged so that groups of two (or a max three) could work together on the worksheets and a device together. This activity does work best with access to Microsoft Excel, but could be adapted to another graphing program. I've added a public Google Drive with the same Excel data and added a tutorial for both programs (Appendices 3 and 4). There are three versions of the graphing sheets, with slightly different standard curve data. There are two worksheets, one for the initial graphing exercise (Part 1), and another for a follow-up on the data using the method of collaboration (Part 2). Teachers should be prepared to help students with graphing and to explore the scientific method. There is an option in the worksheet to complete the final calculations by hand if students are struggling with using the graphing software.

Procedure

Introduction (~15-20 minutes) – This PowerPoint may be utilized to introduce the idea of collaboration and standard curves. If students are unfamiliar with Excel or alternative programs such as Google Sheets, introduce students to the program.

Slide 1: Presentation Title; This PowerPoint may be utilized to introduce the idea of collaboration and standard curves. If students are unfamiliar with Excel or alternative programs such as Google Sheets, introduce students to the program.

Slide 2: I am a graduate student in Virginia studying nitrogen and how it is used as a food source for phytoplankton. I am interested in how different phytoplankton use different types of nitrogen for food. The first picture shows me doing lab work in Virginia. I spend most of my time doing research in Virginia, but I also get to travel to do science. The second photo shows me on a beach in Alaska collecting water. I got to spend two summers in Alaska to study how nitrogen is changing in the Arctic.

Slide 3: Collaboration is a big part of science, Collaboration is working together with your peers or fellow scientists to reach a common goal. All scientists, even student scientists need to collaborate. Scientists collaborate with a lot of different people to reach their research goals. These can include a head scientist, called a chief investigator, students, friends, and many other professors. These scientists may be at the same school or from other universities all over the world! They can even be scientists they meet with a cool idea from a science meeting or members of the local indigenous community. For example, when I was in Alaska we worked with the local Inupiat tribe to coordinate our sampling with their summer hunting season.

Slide 4: This slide shows the author with some collaborators as an example. Brianna is shown her working with collaborators to do an experiment on phytoplankton in the York River in Virginia.

Slide 5: This slide can be used to introduce the scientific method that scientists use to ask questions. A scientist first comes up with a research question. Before designing an experiment to test that question, the scientists gather earlier research to create an informed hypothesis about their question. Once an experiment is well designed (often with collaborators) the scientist begins an experiment. Once the experiment is complete, a scientist assesses their data to check that the results make sense. If they don't they may repeat or redesign their experiment. You can check your data by sending samples to collaborators or other researchers to also repeat your

experiment. Once everything is verified then you can make conclusions. Finally, the results are reported and shared to other scientists.

Slide 6: In today's activity you will collaborate with your fellow students to find the concentration of ammonium in an unknown water sample. Ammonium is a type of nitrogen that is used as food by phytoplankton. Phytoplankton are a type of plant that feed other marine creatures and help create the oxygen we breath!

Slide 7: Ask the students how you find an unknown concentration.

Slide 8: One way to find an unknown concentration is to start with what you do know. Scientists will create a set of samples that they know the concentrations of in order to measure an unknown by creating an equation based on their measurement and experiments with their knowns. These known samples are called standards and the graph/equation is called a standard curve. The standard curve for one ammonium method is linear and we are going to be using some standard data for ammonium provided by Brianna to create a standard curve graph, like the one on the right. Your samples with known concentration are graphed on the x-axis against a reading or collected measurement on the y-axis. A linear line and equation are then added in Excel. That equation can then be used to back calculate your unknown.

Slide 9: As a further visualization, here is an unknown sample with a known Y-value or measurement, placed on your graphed known line as a star. You will use Excel or Google sheets and your equation to solve for the X-value or known concentration of your unknown sample. Today's activity will use a graphing software program graph a standard curve to find the unknown concentration of ammonium in a water sample. This is a good time to break students into pairs or add an additional graphing tutorial.

Slide 10: If students are unfamiliar or need a review of the equation of a straight line this slide will allow you to go over the components of y=mx+b. This will be helpful for the later worksheet activity. As a reminder: y is the point in the y-axis direction, x is the point in the x-axis direction, m is the slope of the line (how steep it is), and b is the y-intercept or what y equals when x is zero.

Slide 11: Optional. Further in-class practice with the y=mx+b equation.

Slide 12: Optional. Further in-class practice with the y=mx+b equation.

Slide 13: Optional. The activity is vague enough that you could apply this to a different type of measurement. The data used to create the activity is from running ammonium nutrient samples. Ammonium can be measured in the lab by adding chemicals to make a new chemical structure that appears blue. So, the more ammonium in the sample, the bluer the tube will appear. This liquid sample is then processed on a spectrophotometer to measure the absorbance of light.

Slide 14: Optional. Continuing after Slide 13, ammonium is measured using a spectrophotometer and the concept of Beer's Law. You do not need to go into the details of Beer's Law, but it describes the attenuation of light through a material. Here it is the blue ammonium which is measured in a 1 cm quartz cell. The absorbance reading obtained from the spectrophotometer is then used to calculate concentration. Depending on students' backgrounds this may be too much information. An alternative visual example that you may use to explain the standard curve is drops of food coloring in water.

Slide 15: Todays activity will use Excel to graph a standard curve to find the unknown concentration of ammonium in a water sample. This is a good time to break students into pairs or add an additional Excel tutorial.

Proceed to activity Parts 1 and 2, return to Slide 16 at the end.

Slide 16: Go over the equations and results for each of the three data versions. Ask the students which groups' method/version looks right/wrong.

Slide 17: Ask students, how do you verify which results are right?

Slide 18: There are lots of good answers to this. If they remember the earlier slides from the scientific method they might answer more experimentation. Another answer is to check results based on an agree standard. This is called standard reference material and they are standards produced by companies that have been measured by multiple scientists. They are an agreed upon check that can be used to help verify your data and results.

Slide 19: Keep Collaborating! Science is about working together, it's not just one scientist alone in a lab!

Activity Part 1

Provided dataset (~30-45 minutes – this may vary depending on student exposure to Excel)

1. Divide the class into pairs (max groups of 3) and pass out one Part 1 worksheet per group.
2. Ensure groups have access to Excel/Google Sheets, a graphing data file with the standard curve data, and the tutorial file.
3. There are three versions of the Excel/Google sheet. Try and have a mix assigned to the pairs. This will be important for Part 2.
4. Have students complete the worksheet using Excel.
5. Question 7 may be completed with a calculator if the students are struggling with entering their equation into the Excel/Google sheet.
6. Once students complete the worksheet have them proceed to Part 2.

Activity Part 2 (~15 minutes)

1. Split up the pairs from Part 1. Pair students with a student from another data version.
2. Pass out the Part 2 worksheet.
3. Have students complete the worksheet.
4. If extra time, have students work on the Challenge Question.
5. Call on groups to discuss their answers as a class.

Share Data with Class and Conclusions (~15 minutes)

1. Regroup the class and have students share their results from Part 2.
2. Once the class shares their data, ask them to identify which data set might be flawed.
3. If students answered the Challenge Question, have them share their answers.
4. Cover final slide on standard reference materials (Slide 12).
5. Cover final thoughts and have students turn-in their worksheets.

Assessment

The main forms of assessment in this activity are the provided worksheets that students will work through and the class' final discussion about the results. As the instructor works through student answers, they should focus on the student's ability to create the Excel/Google graph, manipulate a linear equation, and their understanding of collaboration.

References

Bennett, L. M., & Gadlin, H. (2012). Collaboration and team science: from theory to practice. *Journal of investigative medicine: the official publication of the American Federation for Clinical Research*, *60*(5), 768–775. https://doi.org/10.2310/JIM.0b013e318250871d

Koroleff, F. (1983). Determination of nutrients. In K. Grasshoff, M. Ehrhardt, and K. Kremling (Eds.), *Methods of Seawater Analysis*. Verlag Chemie.

Appendix 1
Graphing Handout

Group names: _____

Date: _____

Dial C for Collaboration: Finding Unknowns with Your Fellow Scientists

Part 1: Using Knowns to Find Your Unknown

In science, we often want to measure a sample for an unknown that we cannot see. To get around this issue, scientists will measure a set of created known samples with the same scientific method used to measure their unknown. This is called a standard curve. Using their known samples, they can then solve for their unknown. In this activity, you will be using the graphing program Excel to solve for your unknown sample.

Unknown Sample: Absorbance reading of 0.0553

Graphing the Data

Using the tutorial handout and the provided graphing sheet, graph your set of known data and answer the questions below.

1. Begin following the tutorial handout. Complete Steps 1 – 3 D (Excel) or to 3 C (Google).

2. Before continue to the next step, write below what you would label each of your scatterplot axes.

   X axis –

   Y axis –

3. Continue through the tutorial steps. Stop when you get to Step 5.

4. You now have the linear equation that explains your known data. This equation is in the form y = mx + b, what do the terms m and b stand for?

   m –

   b –

5. What do x and y terms stand for? *Hint:* What are you graph axes labeled?

   x –

   y –

6. Now you have the equation you need to solve for your unknown nutrient sample's concentration. You have the Y or "Reading" for your unknown sample. Below: Solve your equation for X.

7. Now, continue with Step 5 to use your unknown sample to find X. Alternatively, solve below using a calculator.

8. What is the concentration of your unknown sample?

Group names: _____

Date: _____

Part 2: Collaboration

In science, when we are unsure of an idea or if our science experiment was successful, we double-check our results with our collaborators. Working with collaborators we can make sure our science is good before we share our results with other scientists or the public (students, newspapers, or our friends). This process is often called quality assurance and quality control (QA/QC). Today you will be checking the quality of your own unknown sample concentration.

1. Have each person of your group pair with a student from another set of unknowns.

2. Answer the following questions.
    a. Who are your collaborators in your classroom?

    b. When you do your homework at home?

You and your partner processed the same unknown sample, but had a slightly different set of known data because you work in different science labs. Together, check your results.

3. Calculate the % difference between your two results using the following equation. Assign the larger of the two results as *Concentration 1* and the smaller of the two results as *Concentration 2*. This will ensure that you get a positive answer.

$$\frac{Concentration\ 1 - Concentration\ 2}{Concentration\ 2}\ x\ 100$$

4. Is this more or less than 10%?

If you got less than 10% in question 3, your samples have good quality and both of your data gave similar results. If it is more than 10%, you and your collaborator would continue to work together to figure out what went wrong with the set of knowns that you each used or which of your data is right.

Be prepared to share with the class.

Challenge Question

1. Using the scientific method, what might the collaborators do to check their method if their results produced a difference of more than 10%?

Appendix 2
Worksheet Key

Dial C for Collaboration: Finding Unknowns with Your Fellow Scientists
Part 1: Using Knowns to Find Your Unknown

Graphing the Data

1. Begin following the tutorial handout. Complete Steps 1 – 3 D (Excel) or to 3 C (Google).

2. Before continue to the next step, write below what you would label each of your scatterplot axes.
   X axis – Concentration
   Y axis – Reading

3. Continue through the tutorial steps. Stop when you get to Step 5.

4. You now have the linear equation that explains your known data. This equation is in the form y = mx + b, what do the terms m and b stand for?
   m – Slope
   b – Y intercept

5. What do x and y terms stand for? *Hint:* What are you graph axes labeled?
   x – Concentration
   y – Reading

6. Now you have the equation you need to solve for your unknown nutrient sample's concentration. You have the Y or "Reading" for your unknown sample. Below: Solve your equation for X.
   Version 1: x = (y – 0.0283)/0.0153
   Version 2: x = (y – 0.0188)/0.0169
   Version 3: x = (y – 0.0282)/0.016

7. Now, continue with step 5 to use your unknown sample to find X. Alternatively, solve below using a calculator.

8. What is the concentration of your unknown sample?
   Version 1: x = 1.764706
   Version 2: x = 2.159763
   Version 3: x = 1.69375

Part 2: Collaboration

1. Have each person of your group pair with a student from another set of unknowns.

2. Answer the following questions.
    a. Who are your collaborators in your classroom?
    Other students, friends, teacher, classroom aid, parent volunteer

    b. When you do your homework at home?
    Tutors, other students, friends, teacher, parents, siblings, other family members

3. Calculate the % difference between the two samples using the following equation.

$$\frac{Concentration\ 2 - Concentration\ 1}{Concentration\ 1}\ x\ 100$$

    Version 1 & 2: 22.4%, if they reverse these they'll get -18.3%
    Version 1 & 3: 4.2%, if they reverse these they'll get – 4.0%
    Version 2 & 3: 27.5%, if they reverse these they'll get -21.6%

4. Is this more or less than 10%?
    Version 1 & 2: More
    Version 1 & 3: Less
    Version 2 & 3: More

Challenge Question

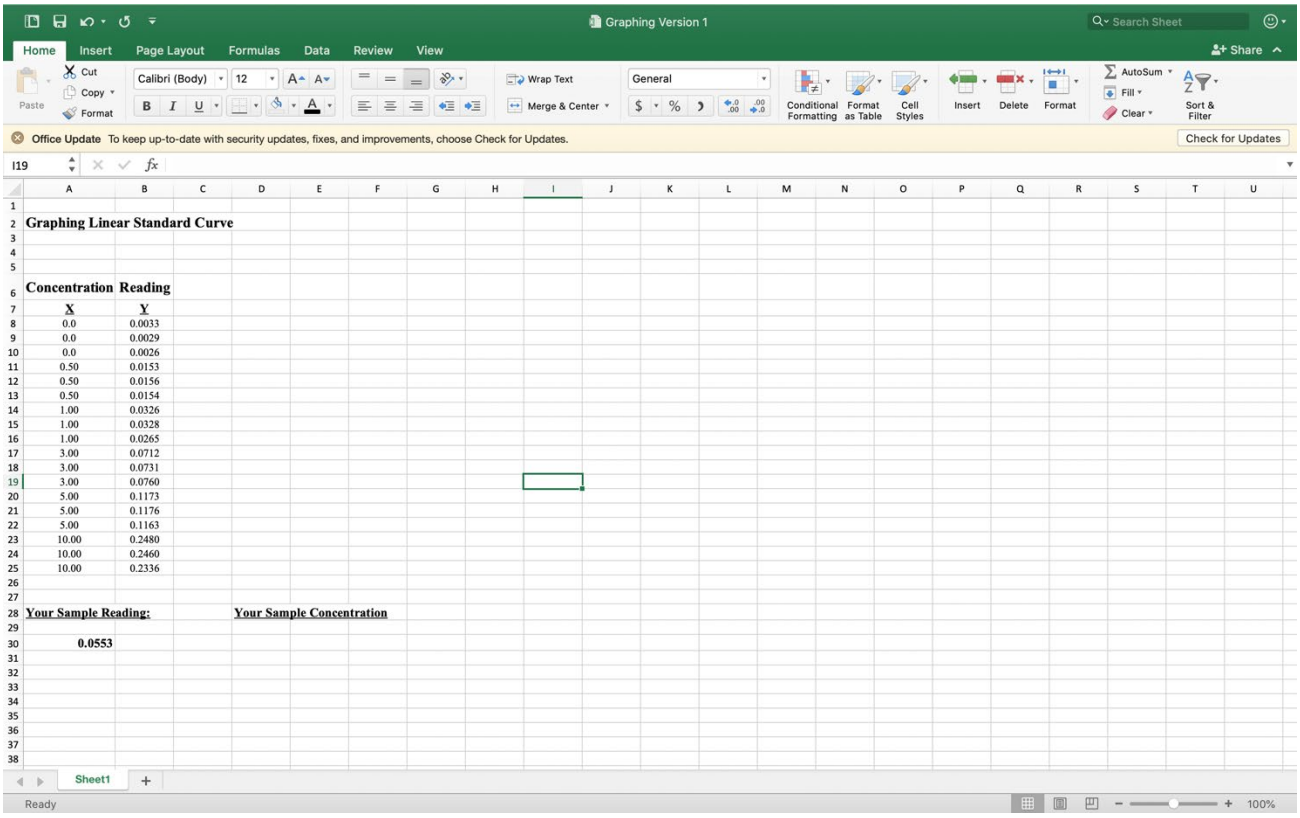
1. Using the scientific method, what might the collaborators do to check their method if their results produced a difference of more than 10%?
    Answers will vary, may include:
        Repeat the experiment
        Repeat the experiment working together
        Try a different version of the standard curve
        Use a different standard curve
        Have another collaborator help

Appendix 3

Excel Tutorial

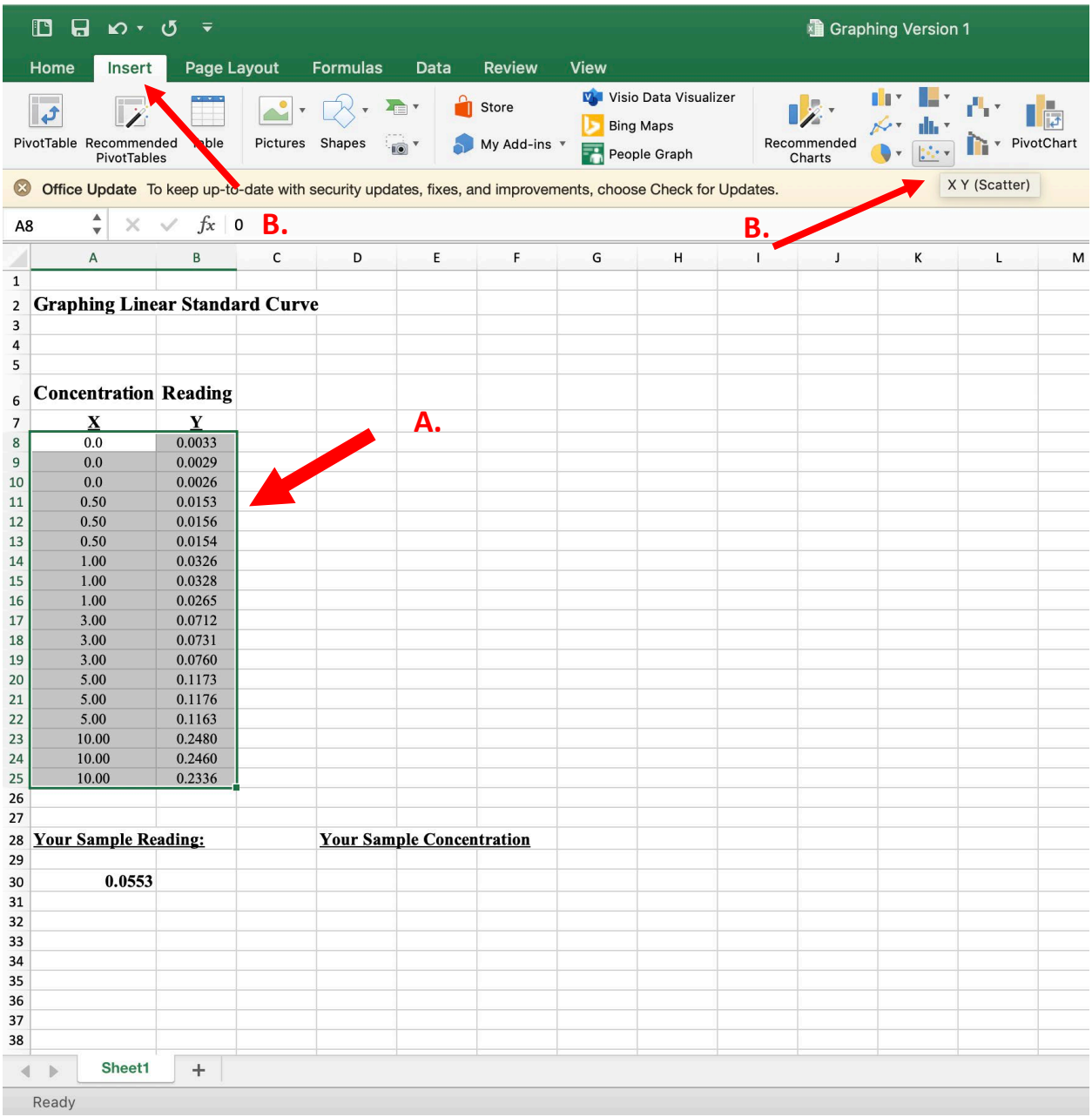
Excel is not hard if you work slow. If you follow this tutorial, you will be able to answer all the questions in today's activity.

Step 1: Open Microsoft Excel sheet with assigned data
Step 2: Take a moment to view your data

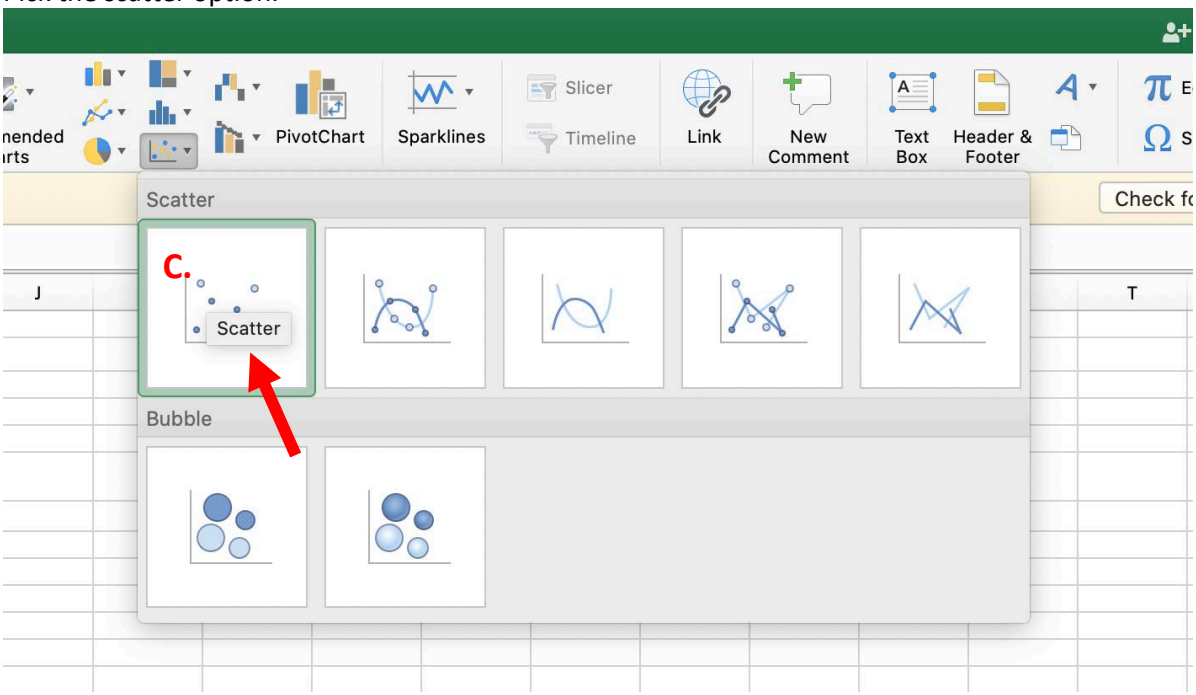


Step 3: Graph your data

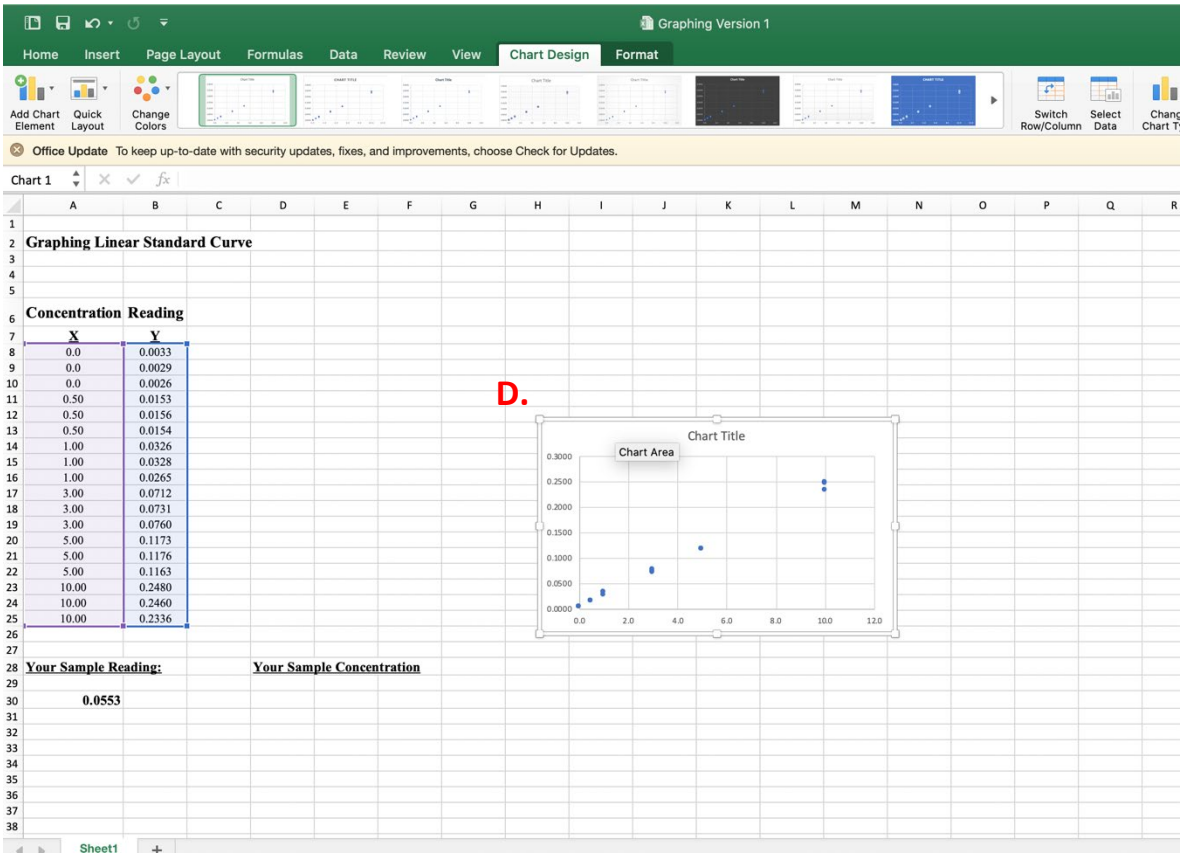
A. Highlight your X and Y data by clicking on one cell and dragging your cursor until all of your data is highlighted.
B. To graph your selected data, first go to the “Insert” tab, then to the “X Y (Scatter)” option.



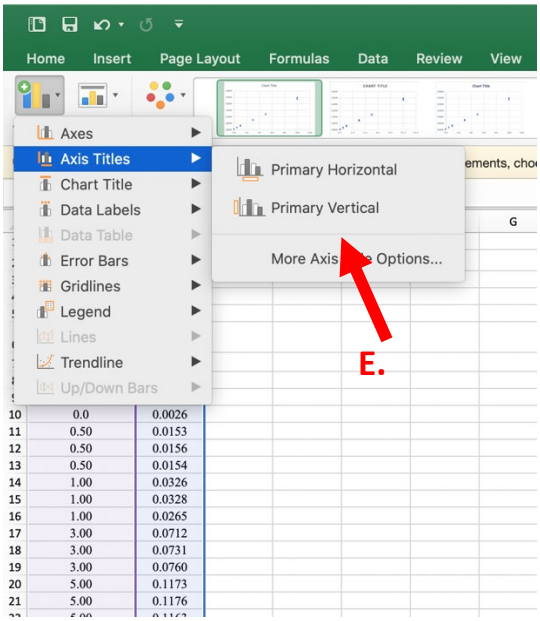
C. Pick the scatter option.



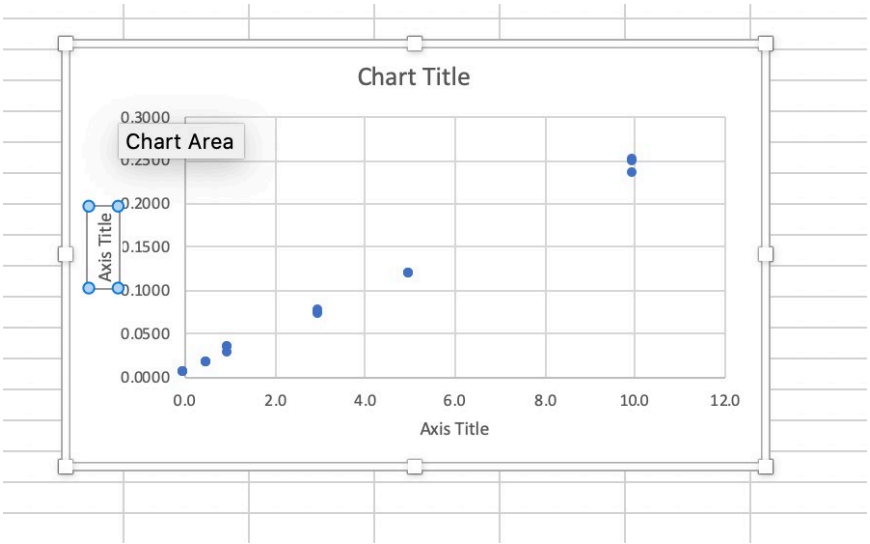
D. Which should produce a graph like the following.



E. To add labels to your X and Y axes, click onto your graph and then go to “Chart Design.” Then click on the “Add Chart Element Tab.” Select the “Primary horizontal” label option and then repeat with the “Primary vertical” label option.

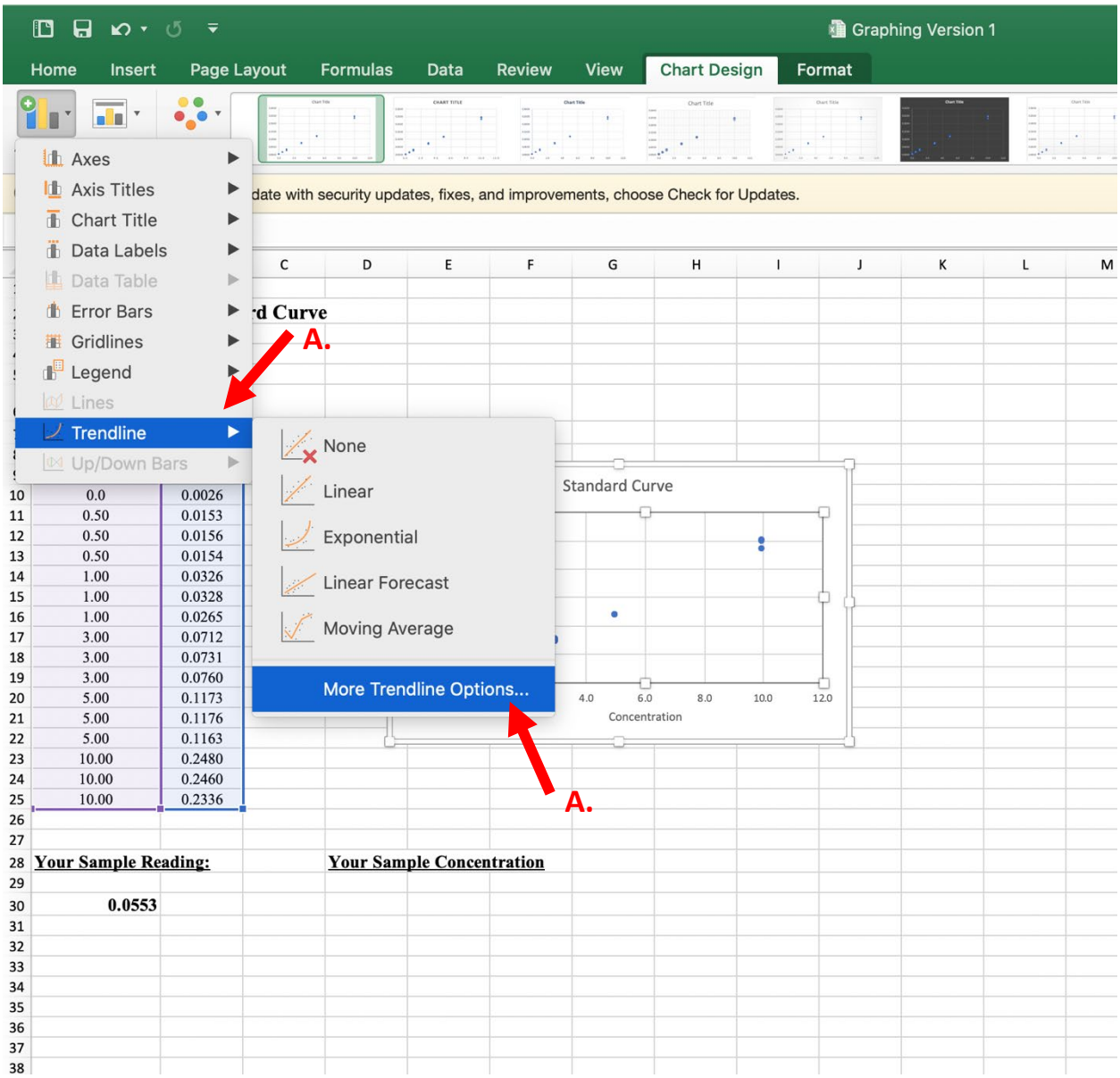


F. Producing the following graph. Click on each axis to add text for an axis title label. Use worksheet question 2 to help you come up with the axis labels. Think about what data measurement is represented by each axis. You should also add a chart title that is descriptive of your data.

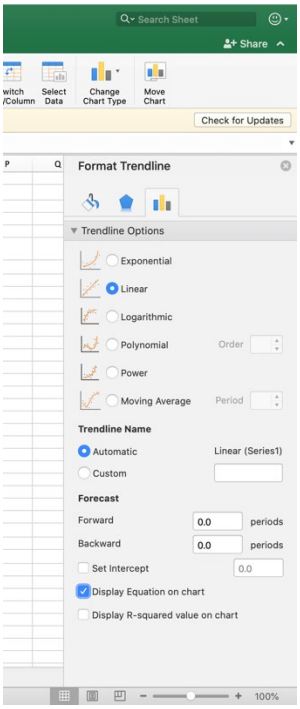


Step 4: Add a linear equation to your graph

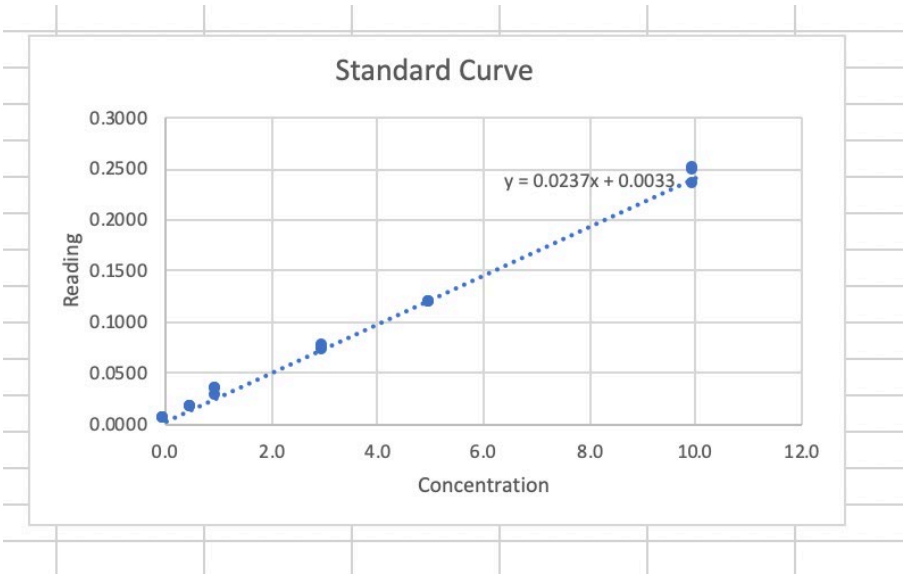
A. Add a trendline to your data points by again going to “Chart Design.” Then click on the “Add Chart Element Tab.” Click on “Add Trendline,” followed by “More Trendline Options.”



B. Once the “Format Trendline” box opens, make sure “Linear” and “Display Equation on Chart” are selected.

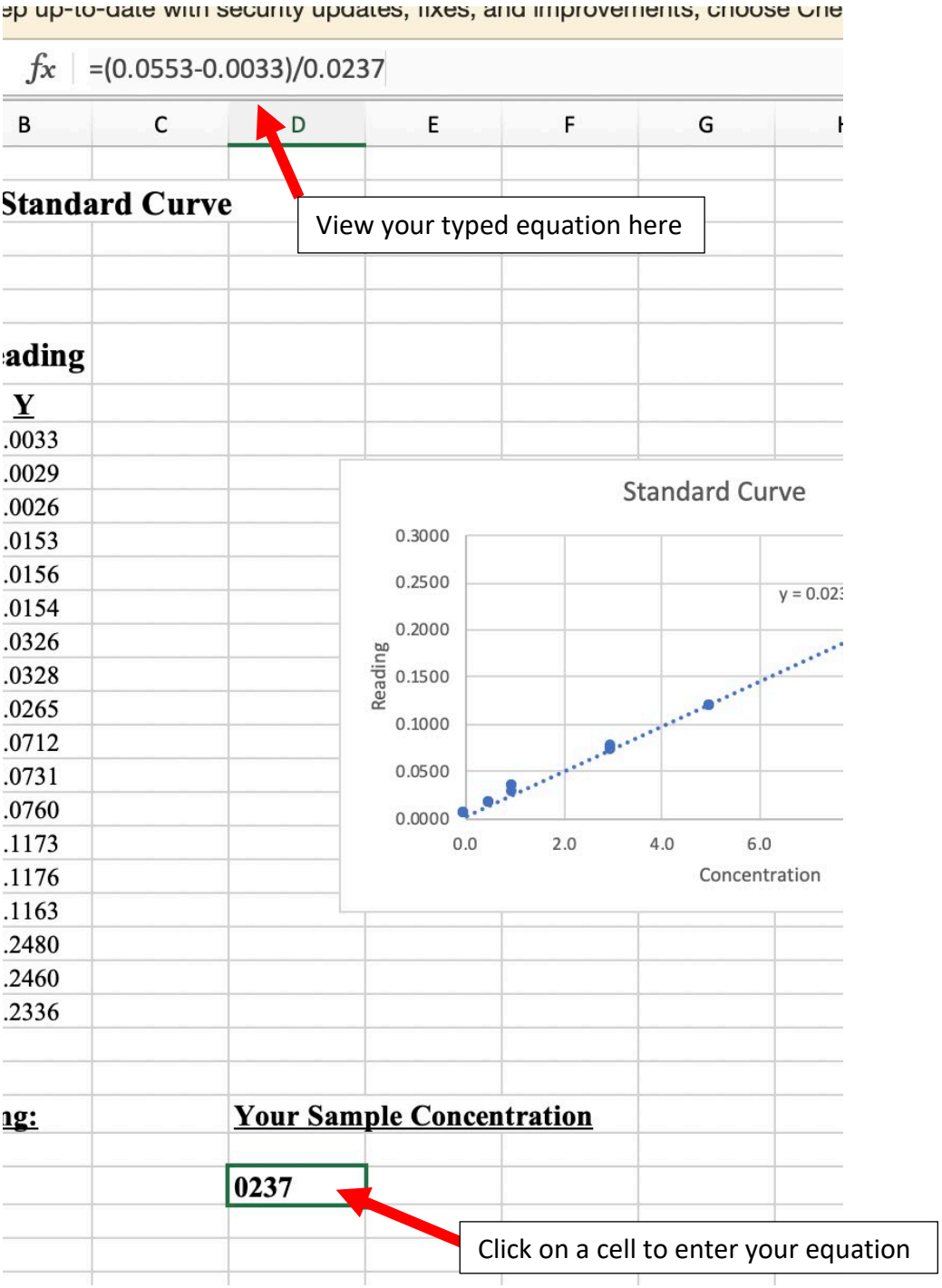


C. Your graph should now look like the following. With an equation in the order of y = mx + b.

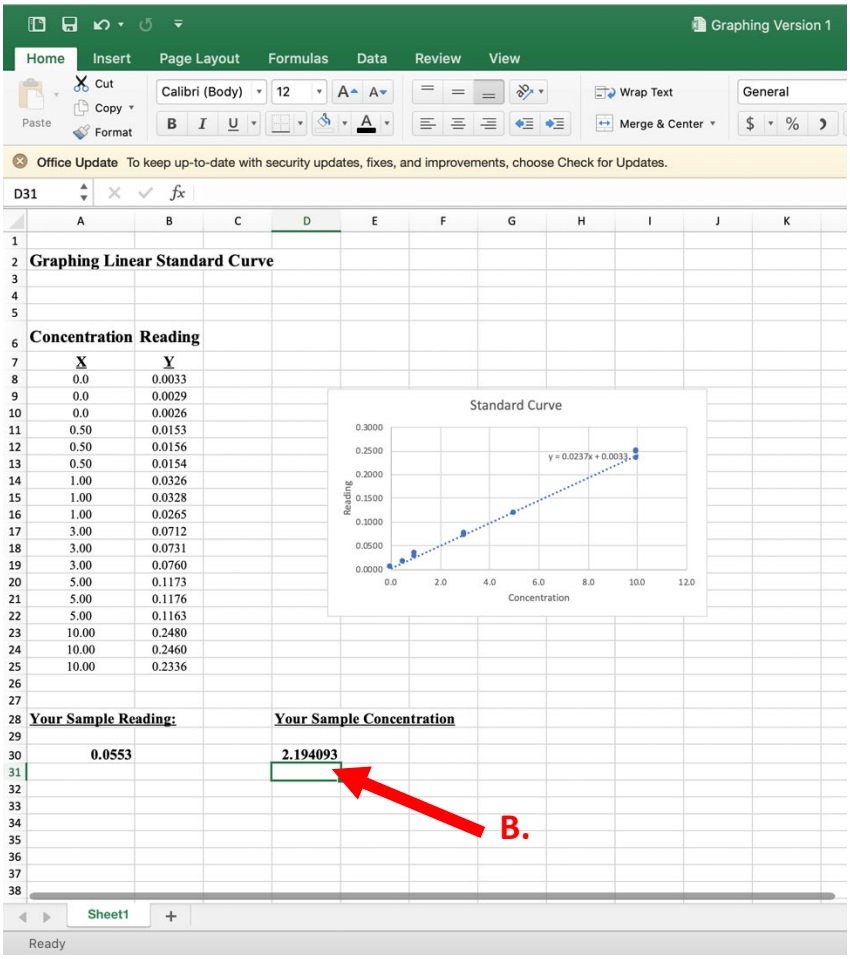


Step 5: Use your equation to solve your unknown

A. Using your equation for your data and your sample reading, calculate the concentration for your sample. Solve for X (Worksheet question 6) and enter your equation into a cell by writing = (y – b)/m. Press enter when done.



B. Now you have your sample concentration!



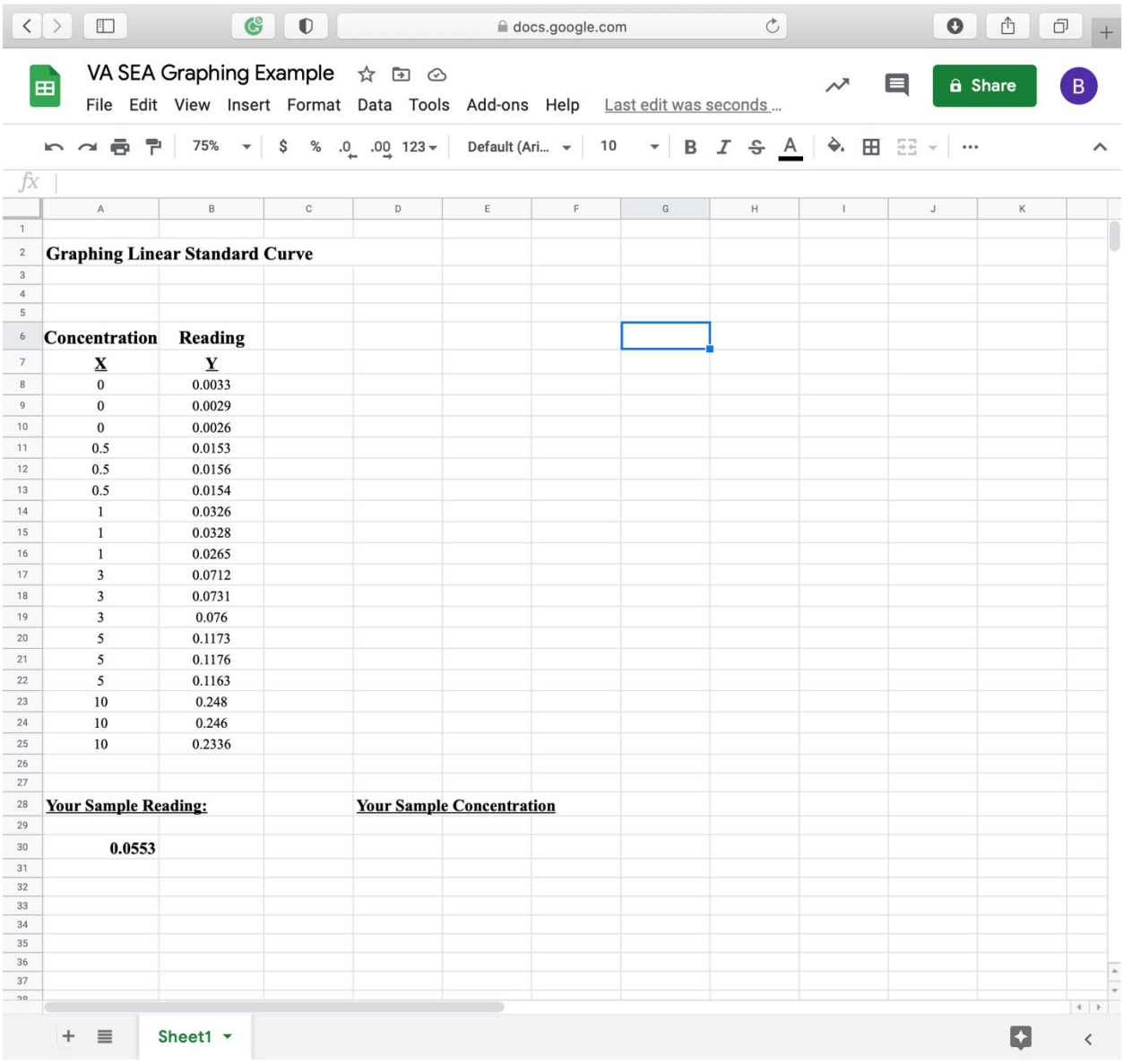
Appendix 4

Google Sheets Tutorial

Google sheets is not hard if you work slow. If you follow this tutorial, you will be able to answer all the questions in today's activity.

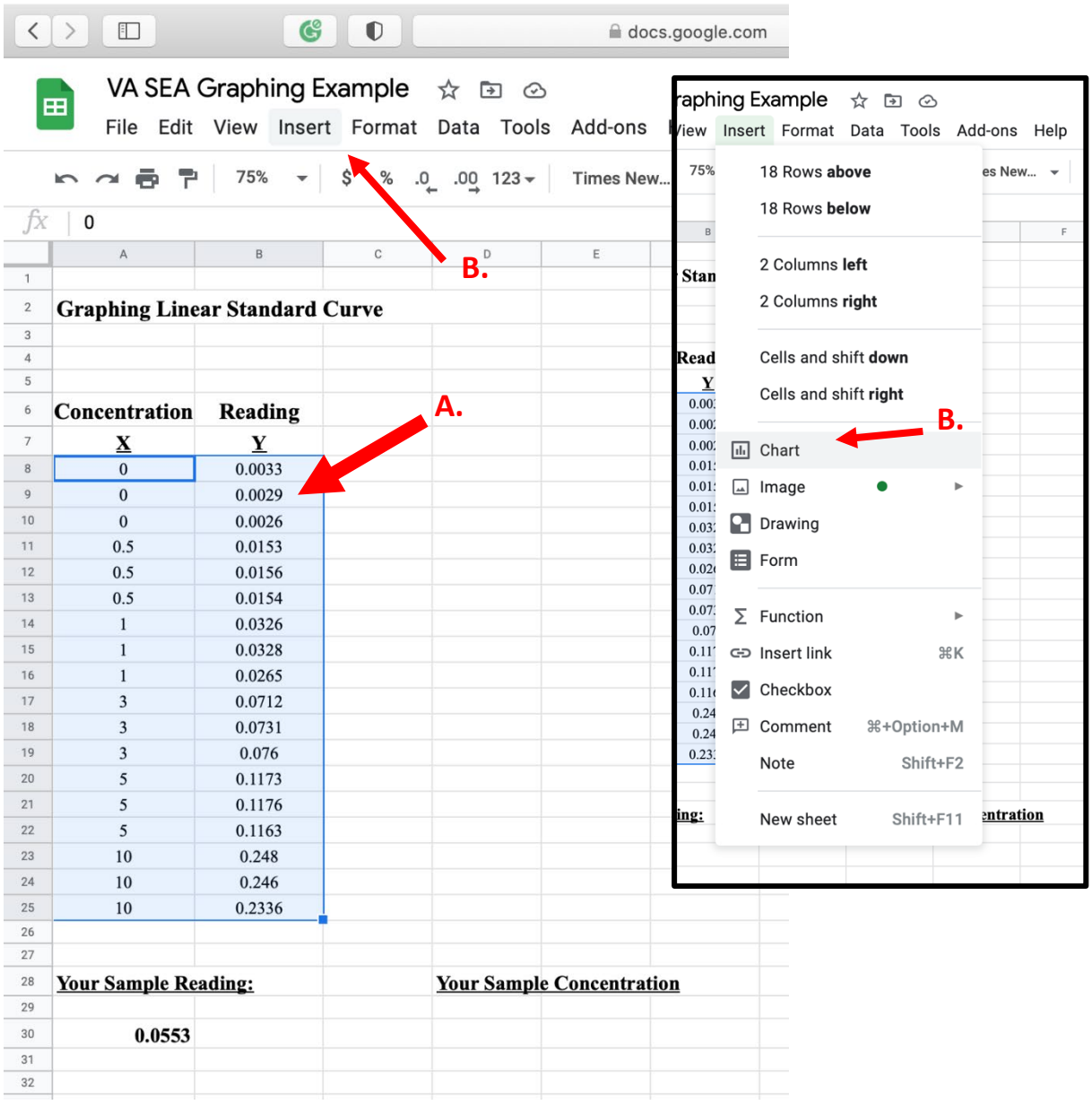
Step 1: Open Google sheet with assigned data

Step 2: Take a moment to view your data

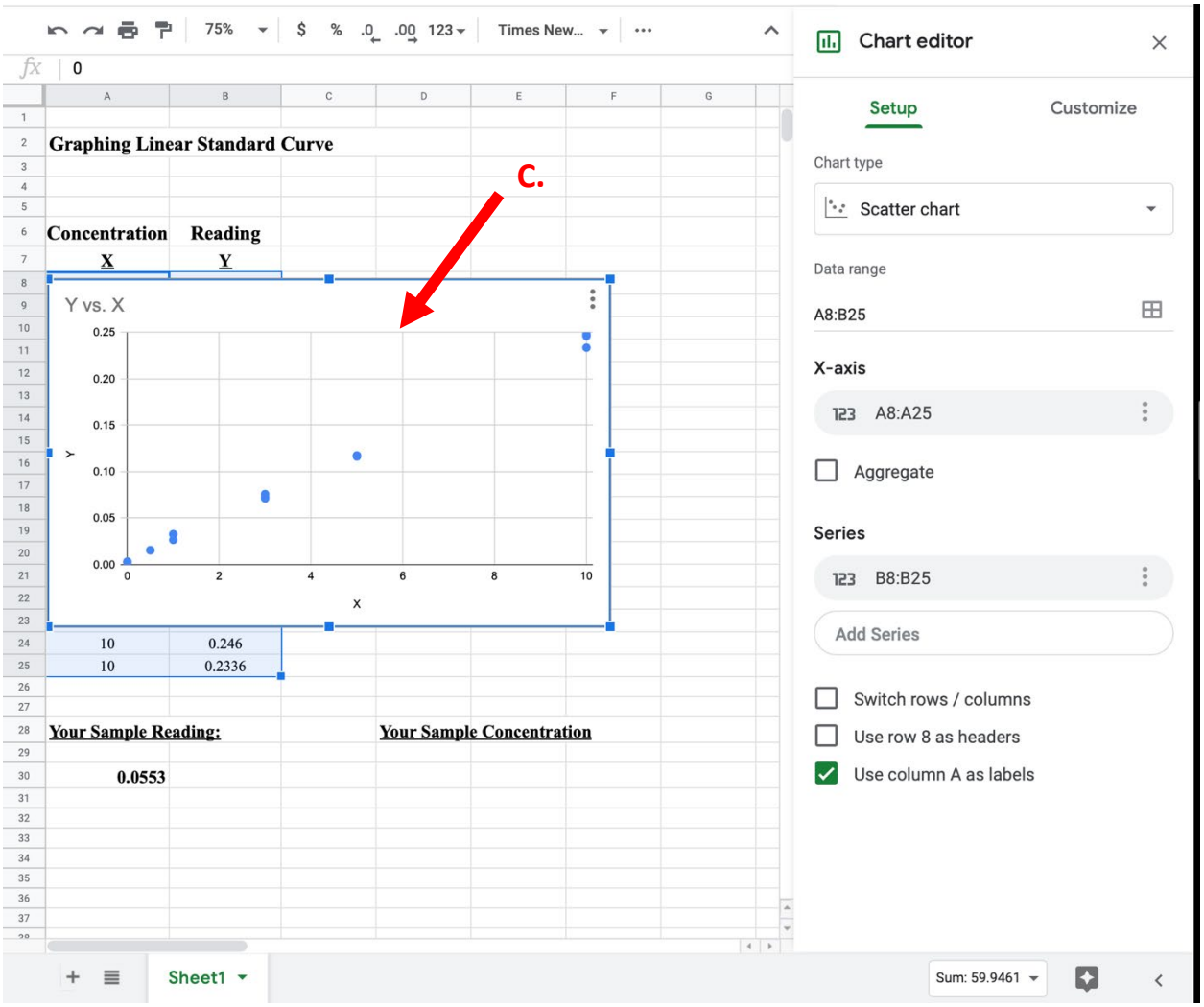


Step 3: Graph your data

A. Highlight your X and Y data by clicking on one cell and dragging your cursor until all of your data is highlighted.
B. To graph your selected data, first go to the “Insert” tab and then select the “Chart” option.



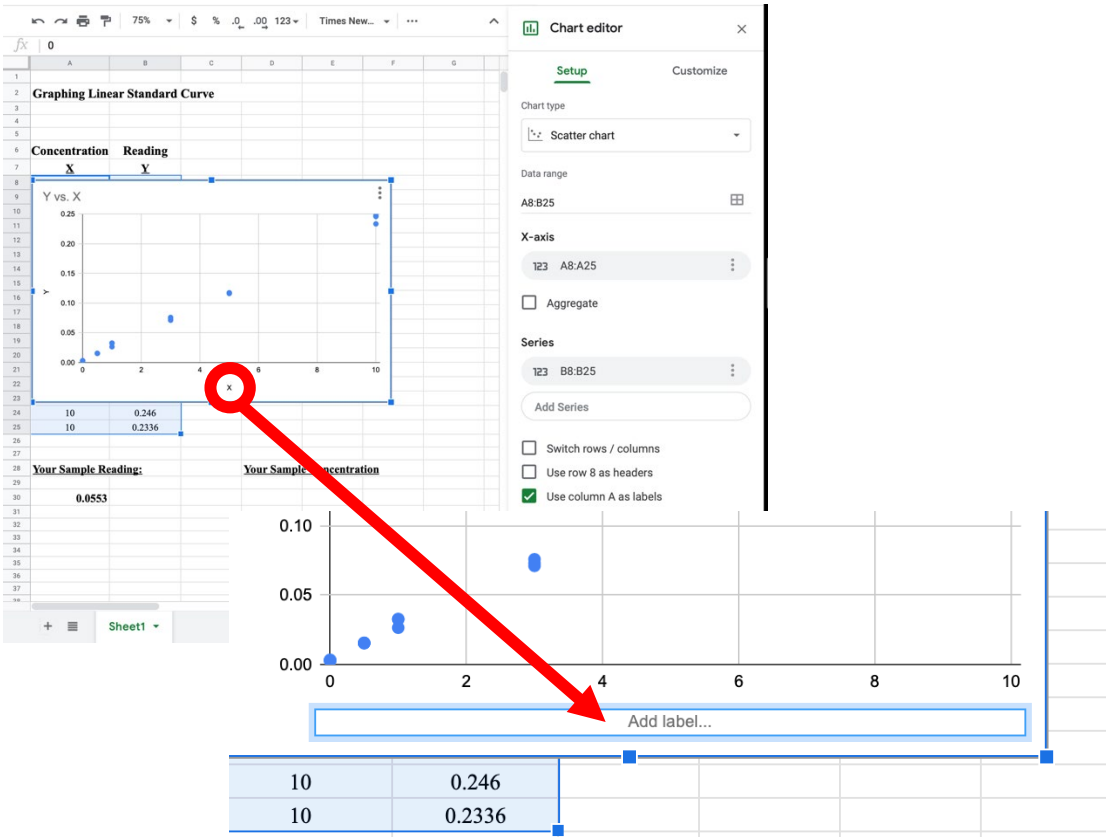
C. Which should produce a graph like the following.



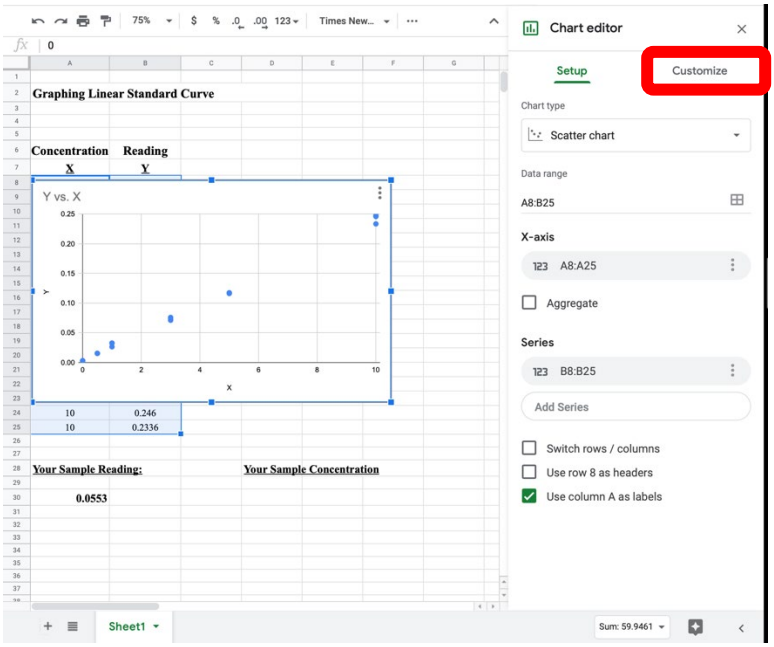
D. Use worksheet question 2 to help you come up with the axis labels. Think about what data measurement is represented by each axis. You should also add a chart title that is descriptive of your data. To add labels to your X and Y axes, you have two options.

1. Click on the X or Y labels on your graph and type.
2. Click on the “Customize” tab. Go to “Chart and axis titles,” before typing your labels in the “Title text” bar. Repeat for the other axis.

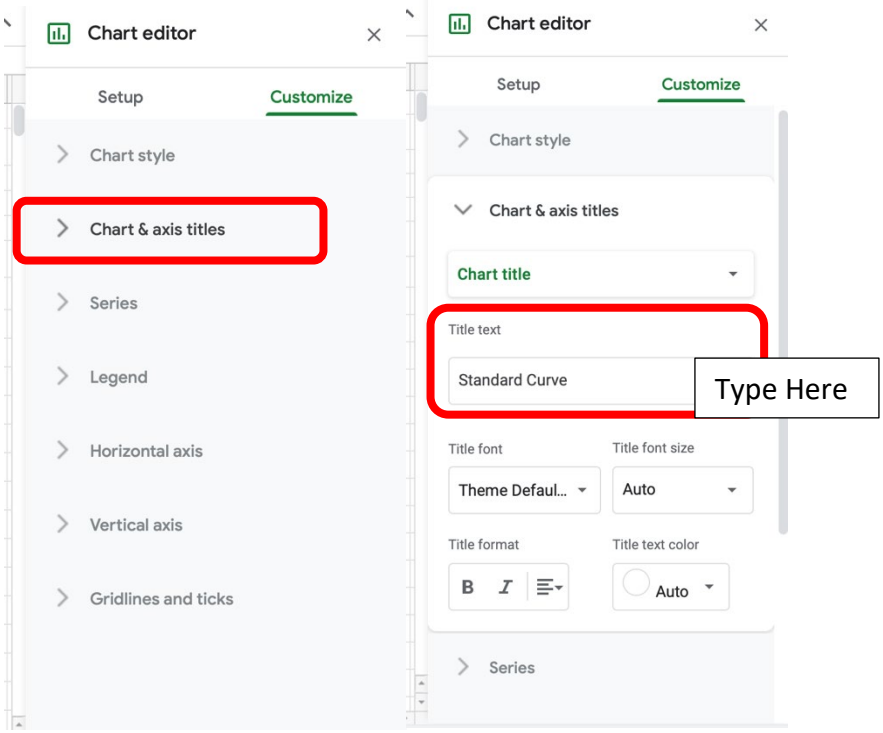
Option 1:



Option 2: First select “Customize.”

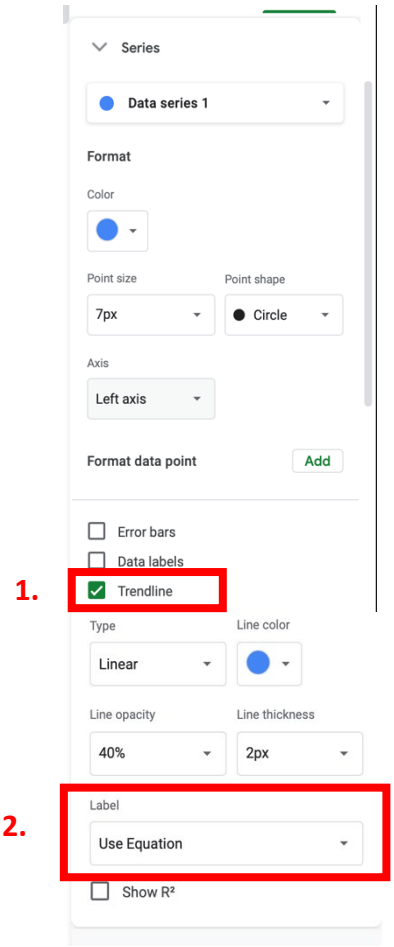


Then go to “Chart and axis titles,” before typing your labels in the “Title text” bar.

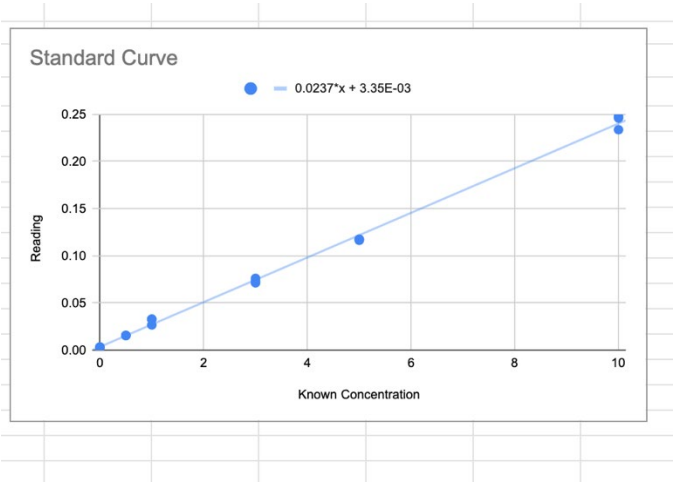


Step 4: Add a linear equation to your graph

A. Add a trendline to your data. On the “Customize” tab, then click on the “Series” tab.
   1. Check the “Trendline” box
   2. Click on “Label” pulldown menu and select “Use Equation”.

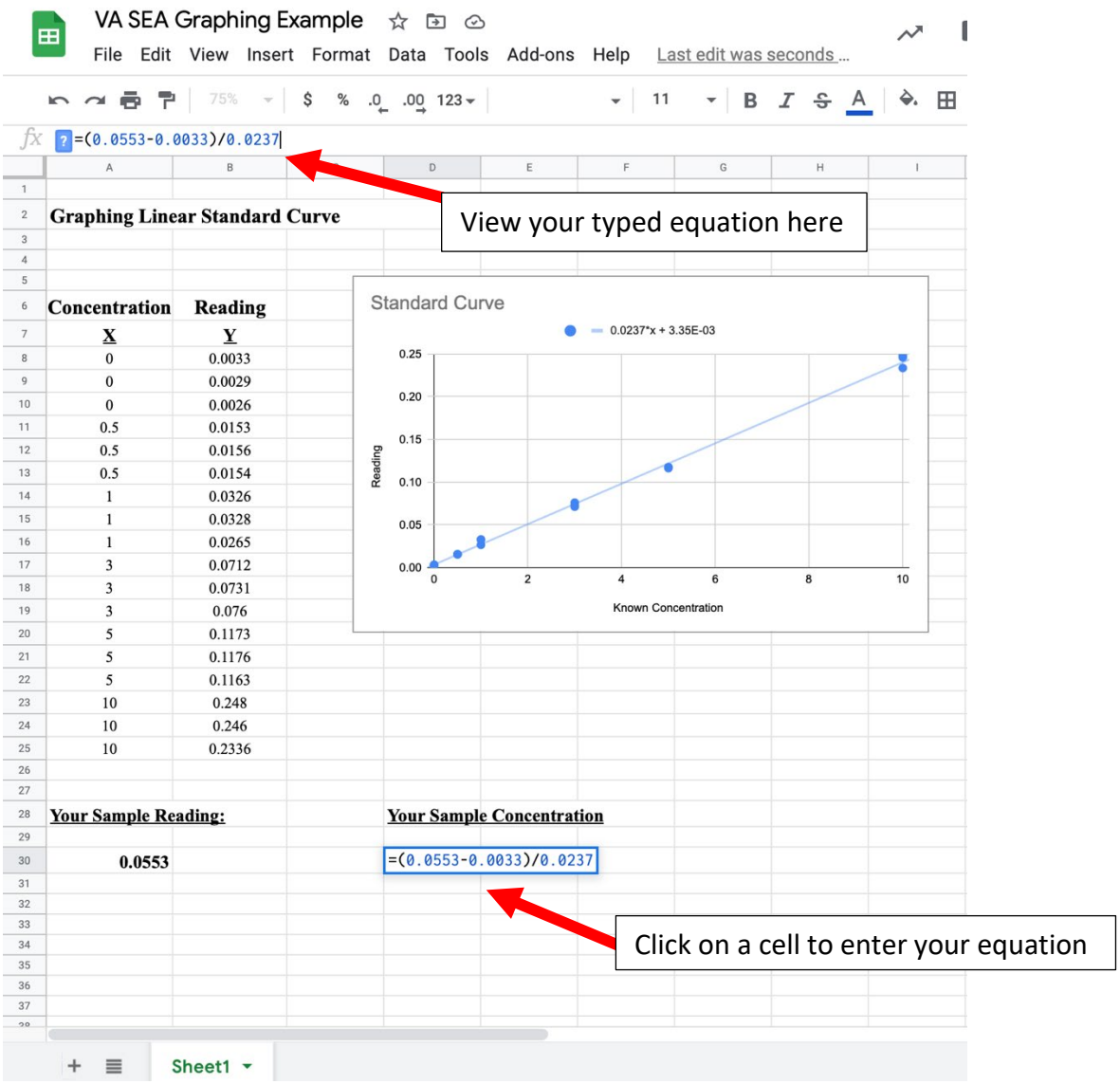


B. Your graph should now look like the following. With an equation in the order of y = mx + b.

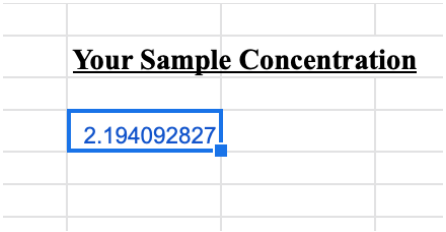


Step 5: Use your equation to solve your unknown

A. Using your equation for your data and your sample reading, calculate the concentration for your sample. Solve for X (Worksheet question 6) and enter your equation into a cell by writing = (y – b)/m. Press enter when done.



B. Now you have your sample concentration!



Graphing Linear Standard Curve

Concentration Reading

X	Y
0.0	0.0233
0.0	0.0226
0.0	0.0225
0.50	0.0304
0.50	0.0309
0.50	0.0314
1.00	0.0420
1.00	0.0417
1.00	0.0402
3.00	0.0754
3.00	0.0726
3.00	0.0768
5.00	0.1294
5.00	0.1270
5.00	0.1274
10.00	0.1726
10.00	0.1676
10.00	0.1683

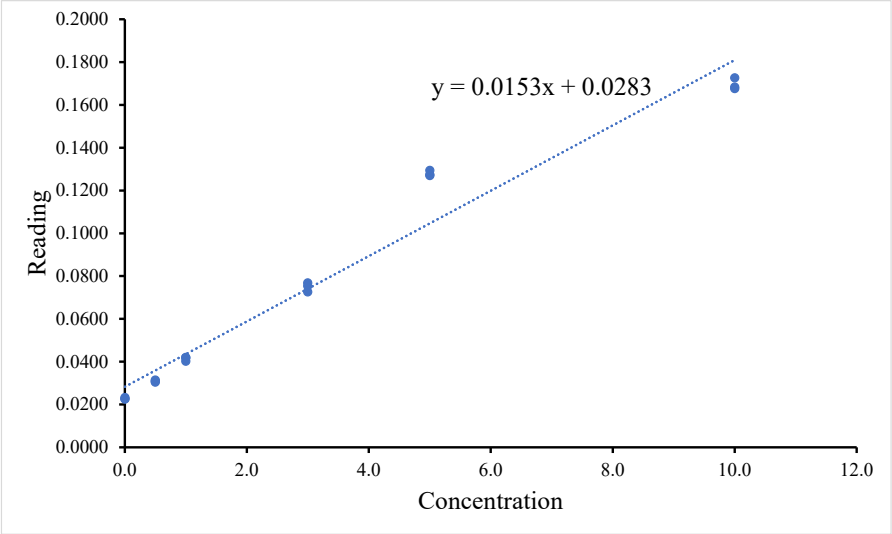
Your Sample Reading:

0.0553

Your Sample Concentration

Graphing Linear Standard Curve

Concentration	Reading
X	Y
0.0	0.0233
0.0	0.0226
0.0	0.0225
0.50	0.0304
0.50	0.0309
0.50	0.0314
1.00	0.0420
1.00	0.0417
1.00	0.0402
3.00	0.0754
3.00	0.0726
3.00	0.0768
5.00	0.1294
5.00	0.1270
5.00	0.1274
10.00	0.1726
10.00	0.1676
10.00	0.1683



Your Sample Reading:

0.0553

Your Sample Concentration

1.764706

Graphing Linear Standard Curve

Concentration Reading

X	Y
0.0	0.0208
0.0	0.0142
0.0	0.0150
0.50	0.0219
0.50	0.0243
0.50	0.0262
1.00	0.0336
1.00	0.0287
1.00	0.0391
3.00	0.0647
3.00	0.0636
3.00	0.0668
5.00	0.1266
5.00	0.1229
5.00	0.1202
10.00	0.1864
10.00	0.1689
10.00	0.1833

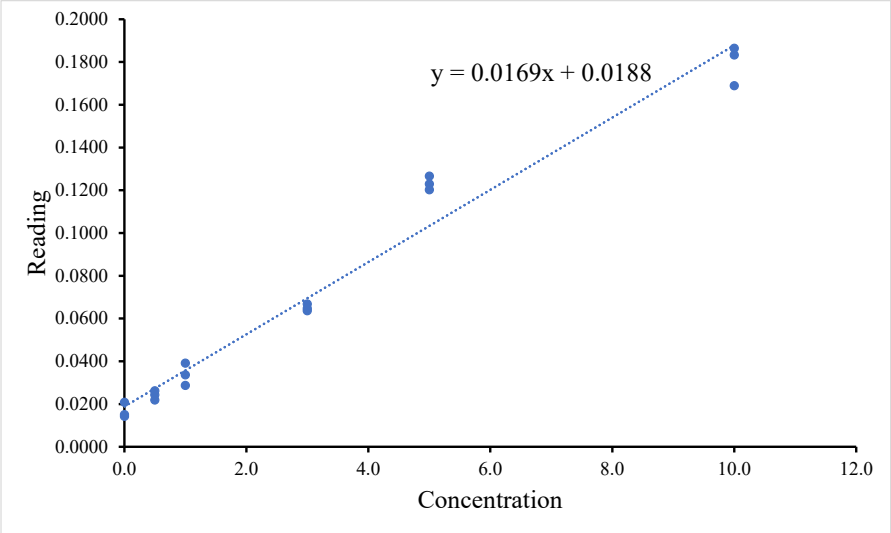
Your Sample Reading: **Your Sample Concentration**

0.0553

Graphing Linear Standard Curve

Concentration Reading

X	Y
0.0	0.0208
0.0	0.0142
0.0	0.0150
0.50	0.0219
0.50	0.0243
0.50	0.0262
1.00	0.0336
1.00	0.0287
1.00	0.0391
3.00	0.0647
3.00	0.0636
3.00	0.0668
5.00	0.1266
5.00	0.1229
5.00	0.1202
10.00	0.1864
10.00	0.1689
10.00	0.1833



Your Sample Reading: **Your Sample Concentration**

0.0553 **2.159763**

Graphing Linear Standard Curve

Concentration Reading

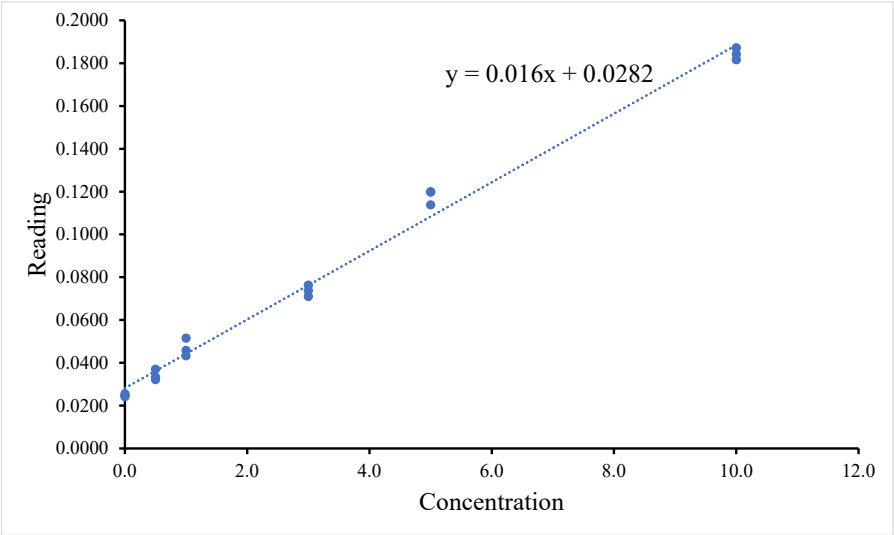
X	Y
0.0	0.0255
0.0	0.0242
0.0	0.0247
0.50	0.0333
0.50	0.0370
0.50	0.0321
1.00	0.0433
1.00	0.0515
1.00	0.0458
3.00	0.0737
3.00	0.0763
3.00	0.0710
5.00	0.1198
5.00	0.1138
5.00	0.1199
10.00	0.1871
10.00	0.1816
10.00	0.1842

Your Sample Reading: **Your Sample Concentration**

0.0553

Graphing Linear Standard Curve

Concentration	Reading
X	Y
0.0	0.0255
0.0	0.0242
0.0	0.0247
0.50	0.0333
0.50	0.0370
0.50	0.0321
1.00	0.0433
1.00	0.0515
1.00	0.0458
3.00	0.0737
3.00	0.0763
3.00	0.0710
5.00	0.1198
5.00	0.1138
5.00	0.1199
10.00	0.1871
10.00	0.1816
10.00	0.1842



Your Sample Reading: **Your Sample Concentration**

0.0553 **1.69375**