Three: Variables are defined and investigations are designed to test hypotheses ...

In a teacher-led class discussion, students will use the basic concepts of experimental design to plan a whole-class experiment designed to test the hypothesis.

1. Use the term **variable** to describe each factor that changes in an experiment. Distinguish between the variable that are purposefully changed or manipulated, the **independent variable**, and the variable that responds, the **dependent variable**.

Lead students to identify the **independent variable** in the experiment by asking them what must be purposefully changed to answer the research question. In this experiment the independent variable will be the concentration of hydrogen peroxide.

Students will identify the independent (IV) and dependent (DV) variables.

2. Lead students to identify the **dependent variable** by asking them how they determined the response to changing the concentration of peroxide. The dependent variable in this experiment will be the time that it takes the disc to rise.

How can I he my students remember th difference between independent dependent variables? L them keep practicing, not with the labs th they do in class also by giving scenarios like t ones provided i chapter 2 of Stu and Research.

Students will identify the factors that will be kept constant in the experiment.

3. Specify **constants** by asking students what factors should remain the same, or unchanged during the experiment. The students will be able to make a very long list of constants based on their discussion of the observations that they recorded during their explorations of the floating disc assay. The list of constants could include:
   - volume of solution in each well
   - whether the solutions are stirred after being mixed
   - temperature
   - grade of filter paper used for making the discs
   - mixing the yeast suspension before taking samples
   - how the filter paper is dipped into the yeast suspension
   - how long the filter paper is dipped into the yeast suspension
   - whether a disc is blotted to allowed to drip before putting it in a well
   - whether the disc is dropped on the top of a well or placed at the bottom
   - the same bottle of peroxide is used (concentration might vary)
   - the same yeast suspension is used by everyone
   - how is the timing done
   - when is timing started and stopped
   - same size drops

What if my students don come up witl of these? It is important that t students recogn that the volume solution in each must be the sam For the rest, go along with wha they say. The students will co to see that varia that are not the independent or dependent varia or held constan become sources experimental er

Students will describe a control for their experiment.

4. Identify a **control** or controls. The control is a standard for comparing experimental effects. The control is used to detect or measure the effects of unforeseen factors, such as the peroxide is too old and almost completely decomposed, or the filter paper itself has something on it that causes the peroxide to fizz. In some experiments, the control is the group that receives no treatment, for example plain water with no peroxide, or a disc soaked in plain water and not in the yeast suspension. Or, the control might be a standard selected based on previous observations, such as peroxide with no water.

Students will specify the number of trials to be done in the experiment.

5. The more data that is generated the better. Will students work individually or in pairs? How many trials will each student/student pair do, that is, how many times will they each go through the entire procedure? How many replicates will each student/student pair test for each concentration of peroxide?

Estimates and Ranges

Even if you cannot weigh out the exact number of grams or moles you need, you can still end up with the specified concentration of material in your solution. Simply adjust the volume in which you will dissolve the substance to reflect the amount you actually weighed out.

For instance, you wanted 18.03 g of sucrose that you would be adding to water to get a total volume of 100 ml. You spooned out some sucrose and note that you actually weighed out 20.5 g.

There's no need to throw the excess away, and, you MUST not return excess chemical into the bottle.

Since you weighed out more than you had planned, you would need to dissolve the chemical in more water than you had initially intended. Actually, you should dissolve the sucrose in:

$$\frac{20.50 \text{ g}}{18.03 \text{ g}} \quad \text{volumes of water.}$$

Notice that the "gram" units cancel out (this is Algebra!) and so you have generated a simple ratio for multiplying with the volume (100 ml).

That is, you multiply 100 ml (the planned volume), by 20.5/18.03 or 1.14

The actual value can show up on your calculator as 1.13699…, but this is too many numbers after the decimal point. You are limited by the actual number of digits in the amount you weighed out, which is 20.5.

Answer:
Adjusted volume should be 114 ml to obtain the desired solution strength when 20.5 g instead of 18.03 g were weighed out. The ratio of 20.5 to 18.03 rounds out to 1.14.

Variables ... continued.

Students will set up a table for preparing the different concentrations of peroxide.

1. Ask the class to decide what the total volume in each well should be. Ideally, the wells should be about 2/3 full. This allows a measurable amount of time for a disc to rise from bottom to top even in the most concentrated peroxide well. It is low enough, though, to prevent easy splashing and mixing between wells. The sample table below is based a drop size of 20 drops/ml, so 40 drops is 2 ml. Students will need to figure this out based on the size of the drops from the droppers they are using.

2. Explain to the class that at least 5 different concentrations of hydrogen peroxide should be tested so that a graph of time vs. concentration can be drawn from the data. Six different concentrations will fill one row of the 24-well plate. Remember that the concentration of peroxide from the bottle is 3%, so well 6 on the table below would contain 40 drops of peroxide, no water and the concentration of peroxide would be 3%.

3. Decide that concentrations below 3% you will want to test.

4. Use the following equation to calculate how to make those concentrations.

$$c_1 v_1 = c_2 v_2$$

(c_1 = 3% which is the initial concentration of peroxide from the bottle)
(v_1 = x which is the unknown, drops of bottle peroxide which will be used)
(c_2 = the desired dilute or final concentration)
(v_2 = 40 drops which is the final or total volume)

sample calculation

(3%) (x drops) = (2.5%)(40 drops)
x = (2.5%)(40 drops)/(3%)

or

x = (2.5%/3%)(40 drops)
x = 33 drops

5. So, based on this calculation, well 5 would contain 33 drops of peroxide. Since the total volume must be 40 drops, then 7 drops of water must also be added in order to achieve a final concentration of 2.5% peroxide. Use the same process to calculate amounts for the other wells.

well	**1**	**2**	**3**	**4**	**5**	**6**
drops of water	33	27	20	13	7	0
drops of peroxide	7	13	20	27	33	40
total volume (drops)	40	40	40	40	40	40
concentration of H_2O_2 (%)	0.5	1	1.5	2	2.5	3

Each student should have a copy of the table, which becomes part of the detailed procedure.

How much will the sizes of the drops vary even though students are all using the same kind of dropper? A constant drop size can be achieved by keeping the dropper in a vertical position as the drops are formed. When the dropper is tilted to the side, drops of various sizes seem to slide out. Students can test this qualitatively by looking at drop size on a piece of saran wrap or quantitatively by determining and comparing the mass of the drops.

Data Analysis Terms

Range:

- The spread of scores is indicated by an expression of the difference between the lowest and highest scores.

Mode:

- The most frequently occurring score.

Median:

- The midpoint of a distribution, above which half of the scores occurred and below which half of the scores occurred.

Mean:

- More accurately called the arithmetic mean, it is defined as the sum of scores divided by the number of scores. Or, put in other terms, the mean is the sum of measures observed divided by the number of observations.

Standard Deviation:

- The standard deviation is a statistic that tells you how tightly all the various examples are clustered around the mean in a set of data. The standard deviation is a statistical measure of the precision in a series of repetitive measurements. The standard deviation is the square root of the average squared deviation from the mean that tells them how widely the values in a set are spread apart.

- A large SD tells you that the data are fairly diverse, while a small SD tells you the data are pretty tightly bunched together (preferable result).

Variables… *continued*.

Students will write a detailed procedure for the class experiment.

This will be easy for the students to do since all the variables and constants have been identified and the dilution table has been drawn. Each student should be able to write a draft of a detailed procedure independently at this point. It could be done in class or as an outside of class assignment.

Students will need to read each other's procedures and make necessary revisions to assure that when the experiment is done, everyone in the class will be following exactly the same steps.

Four: Carry out the class experiment …

Students will

Make a class data table.

A sample spreadsheet with class data appears in the appendix

Use of spreadsheet software is recommended. Use Excel or ClarisWorks spreadsheet software depending on your school's technology requirements and resources.

Set up one computer with the necessary headings. (See Appendix for an example.)

Encourage a pair of your students to prepare the spreadsheet with appropriate headings.

Encourage another pair to set up formulas related to the headings to automatically calculate averages, standard deviations, charting.

When all teams have entered their data, give a photocopy to each student.

Have some student teams perform calculations by hand, others with a programmed calculator, and others to make their analyses on a copy of the spreadsheet software file.

Ask students to jigsaw and then compare ease, accuracy and understanding of the arithmetic, statistical, and graphing functions. Also ask students to compare the understanding they gained from the process and new questions that arose about the subject of the experiment as they performed the mathematical analyses.