d. soak samples in each for 15 minutes, remove from beakers, rinse completely and set on paper towel to dry

e. visually inspect and measure each sample as was done prior to soaking, note results and dimensions

2. Test for effectiveness in clearing clogs

a. prepare test pipes by packing two 12" pieces of ABS pipe with equal amounts of small twigs or roots (from same tree in yard if possible)

b. pack equal amounts of a mixture of hand soap and vegetable shortening on top of the twigs so that the soap mixture and the twigs are pressed together

c. place the pipes upright in 2 separate buckets and pour equal amounts of tap water into each pipe

d. pour recommended amount of Sodium Hydroxide in one pipe and Muriatic Acid in the other

e. wait recommended time from Sodium Hydroxide container or until fluid flows out of the bottom of the pipes

f. note the time and inspect the clog, note if the condition of the twigs and the soap/grease mixture, photograph if possible

g. measure the volume of fluid that passed through the clog, if any

h. carefully clean up the equipment and dispose of the spent chemicals

VI. Execute Experiment/Collect Data

Execute the procedure. Collect data, samples, photos, video, etc.

VII. Analyze Data

Procedure should include what to look for in the results. Analyze results and process any data required. Use valid statistical procedures. Calculate averages and account for sources of experimental error.

✧ *Example*

Any reduction in wall thickness of the pipe samples indicate erosion due to the chemicals, compare the magnitudes if changes were present in both samples. Include the control sample in this data. It could be possible that tap water causes changes in the plastic.

If both clogs were penetrated by each chemical, note the volume of water that passed through the pipes, how long it took to start to flow, and how fast it flowed after it started. Document the relative condition of the clogs and which chemical did best with what part of the clog.

Note: Some data far outside of the expected range may result from faulty equipment or contamination and should not be included in the sample data. Throw out anomalous data (i.e. throw out the high and the low)

VIII. Draw Conclusions/Document the Results

If you were right, restate your hypothesis. If not write down what you can conclude from the experimental results in the same form as you would an hypothesis.

In either case reference the data that you are basing your conclusion on.

Put data in digital form (i.e. spreadsheet/database application) Create appropriate charts/graphs. Use illustrations when appropriate. Also include possible scenarios where conclusion may not be valid.(i.e. Caveats/Disclaimers)

✧ *Example: Haven't done experiment yet so don't know!*

In Closing

If your test was well thought out and executed and your data was accurately collected and analyzed, and your conclusions well founded, you have successfully added the word 'scientific' to your experiment.

Congratulations, you are a scientist!

should provide you with evidence that could be used to pursuade them to agree with your position. This is best done with careful data collection and rigorous statistical analysis of the data.

In these cases you should move from knowing that something will occur to knowing how often it will occur, when, under what circumstances, and to what magnitude. If you can also determine why you have done a completely thorough job.

II. Research

Investigate all aspects of the problem that you can imagine including causes, effects, and similar or analogous situations.

✧ *Example*
Acids combine with bases and produce salts. Soaps are bases. Sodium Hydroxide is a strong base. Acids react with some plastics. Acids can damage sinks and other plastic plumbing pieces A rooter machine can be rented for $25/day. It will cost $100 to have a plumber come out and fix it

III. Restate The Problem

This is a good time to use OTBT. Step back at this step and ask yourself, "Is this really the problem, or is it a result of a larger problem?"

✧ *Example*
The real problem is the plugged drain so there are really 4 choices; the two chemicals, renting a rooter machine, and calling the plumber. It would not hurt to mention the other solutions as options however you were asked to help select between the two chemicals so that is what you should do. *From our research we know that we must also be concerned with damage to the plumbing system as well so it is possible that neither chemical would b safe to use.*
Restated Problem: To help determine which chemical, Sodium Hydroxide or Muriatic Acid, should be used to clear a clogged drain without damaging the plumbing system.

Note: Remember that when asked to design an experiment for a school assignment, or on a job, you should try to solve the problem as stated by your teacher or your boss as originally stated as they may have more information or experience than you do or they may have other reasons you are not aware of for stating the problem as they have.

IV. Form Hypothesis

State what you think is going to happen, and why. Consider the possibility that the results do not match your expectations. What would that indicate?

✧ *Example*
Because the clog is a base, soap, the acid should be the best solution for clearing up the problem. Acids normally are corosive to metals but the plumbing is plastic so it should not be damaged.

V. Write Experiment/Test Procedure

Write a detailed, step-by-step, set of instructions that someone else could follow to complete your experiment. Include 'controls', specific quantities, sources for materials, timing, and potential sources for errors.

✧ *Example*
1. Test pipe for damage from chemical *a. take 3 samples of ABS pipe that matches that found in the plumbing system, measure and note their dimensions and note their physical appearance* *b. label 3 glass beakers and put the pipe samples in each* *c.. pour tap water in one beaker, Muriatic Acid in the second beaker, and Sodium Hyrdoxide in the third. Make sure the pipe samples are completely covered in each.*

Experimental Design

The following is an example of the use of the scientific method in solving an every-day real-world problem. It is intended to provide a template that may be used to guide students in designing experiments for assignments, projects, or for every day life.

This is my version of the scientific method in application, others may have their own variations. Theirs may arrive at the same answer or a different one while both may be equally valid.

That is the beauty of real world problem solving, rarely is there only one 'right ' or 'best' answer. The number of equally valid solutions to a particular problem are limited only by the imagination of those seeking them.

We've all done it

You have probably done this countless times in your life; encountered a problem *(is the water hot?)*, had a feeling about what may happened *(its not steaming*), tested it to see if you were right *(jumped in)*, got some (unexpected) results *(got burned)*, drew a conclusion *(water can be hot enough to burn without steaming)*.

Hopefully you have learned from those experiences and modified your behaviour. That is called *learning* and those *experiences* were all examples of *experiments.*

Adding Science

Engineers and Scientists do the same thing daily however in a much more structured manner. The structure they follow is a general procedure that distinguishes their efforts from those every day experiences most people use as the basis for their 'common sense'.

By using the ***Scientific Method*** they make the results of their investigations reproducible, credrible, reliable and, consequently, more useful to other. If done well, they also get to the 'best' answers in the most expedient manner possible with a minimum of damage or risk.

Try this on a problem you have tackled recently and see if you would have approached it differently.

Example Problem - The Homeowners Nightmare

Mr. Green's plumbing backed up last week and my two neighbors, Mr. Black and Mr. White, each had very strong opinions about how to un-stop it. Both solutions involved chemicals I could buy at the hardware store.

- ✧ Mr.Black told me that he always used Sodium Hydroxide crystals that he got from Home Depot.
- ✧ Mr. White told me that he always used pool acid (muriatic acid) poured at full strength down one of his toilets.

Mr. Green's sewage pipes are ABS plastic. In the past his plumbing has become clogged when roots from a tree in the yard grew inside the pipes and became clogged with excess soap. *Whose advice should Mr. Green follow?*

✧ *Your Task:* Design an experiment using the *Scientific Method* to help Mr. Green make the best choice. I want to clear the pipes but not damage them while doing so.

Note: This is a true story, the names have been changed to protect the uneducated.

I. Problem/Purpose Statement

Write out explicitly the problem that you are trying to solve, the question you want to answer, or the thing you want to understand better. In other words, why would someone want to do this experiemt.

Include a statement of the 'given' and any relevant background information.

✧ *Example*

Problem: To determine which chemical, Muriatic Acid or Sodium Hydroxide, would be best suited to clearing a clogged drain**.**

Note: If you already know the answer then you should be looking to understand its causes and effects better or be seeking to develop empirical evidence to justify your opinion.
Imagine that you were on a planet where the aliens knew nothing of plumbing, acids, bases or even plastics. Your experiment

