Tatum Ridge Science Fair Packet 2015-2016

When is each step due?

Steps of the Scientific Method	Due Dates
Ask a Question: The scientific method starts when you ask a question about something that you observe: How, What, When, Who, Which, Why, or Where? And, in order for the scientific method to answer the question it must be about something that you can measure, preferably with a number. **Safety Assessment Form:** This form must be filled out properly and signed in blue pen only.	**October 7th** Topic Your Question/Purpose Project Proposal Form
Do Background Research: Rather than starting from scratch in putting together a plan for answering your question, you want to be a savvy scientist using library and Internet research to help you find the best way to do things and insure that you don't repeat mistakes from the past. You will begin research at school and continue to work on it at home by taking notes in your logbook. Any unfamiliar words must be noted in logbook and defined. **Bibliography:** All research must have sources cited. Students must have at least 3 sources and in correct format.	**October 16th** Background Info Planning sheet Background Information/ Definitions of Unknown Terms Bibliography
Construct a Hypothesis: A hypothesis is an educated guess about how things work: "If _____*[I do this]* _____, then _____*[this]*_____ will happen." You must state your hypothesis in a way that you can easily measure, and of course, your hypothesis should be constructed in a way to help you answer your original question. Remember, this is a prediction of how your experiment will turn out based on the information you have gathered from your research. **Variables:** Remember to include the variables in your logbook and board. The independent variable is what is changed in the experiment. The dependent variable is what it measured. The constant variables are what remains the same in the experiment.	**October 21st** Variables Hypothesis
Test Your Hypothesis by Doing an Experiment: Your experiment tests whether your hypothesis is true or false. It is important for your experiment to be a fair test. You conduct a fair test by making sure that you change only one factor at a time while keeping all other conditions the same. So, the experimental procedure explains what you are doing in your experiment. Be sure to include what materials you will be using and that your measuring materials are *metric.* You should also repeat your experiment a total of 3 times to make sure that the first results weren't just an accident. You also need to include an average of the trials.	**October 23rd** Experimental Procedure Materials List
Graphs/Charts/ Results: Once your experiment is complete, you collect your measurements and analyze them to see if your hypothesis is true or false. Be sure you use the correct type of graph for your experiment. It must show 3 trials and an average. All measurements must be metric. Results should also be in written form. They are to be statements that show you have analyzed your graphs and charts. **Abstract:** Follow the correct format provided. **Conclusion**: Scientists often find that their hypothesis was false, and in such cases they will construct a new hypothesis starting the entire process of the scientific method over again. Even if they find that their hypothesis was true, they may want to test it again in a new way. This is where you answer your problems statement and tell whether your hypothesis was correct or not. It must have evidence from your research to support it. Further study must also be included as well as relevance to the real world.	***November 6th*** *Data Analysis & Graphs/ Results* **November 11th** *Abstract* **November 13th** Conclusions

Communicate Your Results: To complete your science fair project you will communicate your results to others through a display board and logbook. Professional scientists do almost exactly the same thing by publishing their final report in a scientific journal or by presenting their results on a poster at a scientific meeting.	**November 30th** Logbook/ Boards/Safety Forms Due **December 2nd** Tatum Ridge Science Fair

Even though we show the scientific method as a series of steps, keep in mind that new information or thinking might cause a scientist to back up and repeat steps at any point during the process.

What makes a good Science Fair project?

Key Information:

- There are several resources at www.sciencebuddies.org to help you decide what your science fair project will be about:
    - The **Topic Selection Wizard** asks you a series of questions about everyday interests and activities, then recommends an area of science and science fair project ideas that are best for you. We will do this in class.
    - The **Science Fair Project Ideas** page lets you browse through hundreds of science fair project ideas. (http://www.sciencebuddies.org/science-fair-projects/project_ideas.shtml?From=body) Once you narrow down a topic, find the specific area your project fits into (example: "biology" or "Earth Science") and write it down on your topic paper.

- Once you find a general topic that interests you, write down the question that you want to answer. A scientific question usually starts with: How, What, When, Who, Which, Why, or Where. For example, if you are interested in robots, your question might be "How much current does a robot's arm use to lift a weight?"
- Can you design a fair test to answer your question? A "fair test" requires that you change only one factor (variable) and keep all other conditions the same. If you cannot design a fair test, then you should change your question.
- Your science fair project question should involve factors or traits that you can easily measure using a number. Or, factors or traits that are easily identified, like colors.
- Read through the list below of Science Fair Projects to Avoid to make sure you set yourself up for success! If your topic is close to something on the list, it is best to pick something else.

Finding an Idea for Your Science Fair Project

- One of the most important considerations in picking a topic for your science fair project is to find a subject that you consider interesting. You'll be spending a lot of time o it, so you don't want your science fair project to be about something that is boring.
- Finding a topic is the hardest part of a science fair project, and sometimes you just need a little help focusing on what sorts of topics would be of interest to you. To help you find a science fair project idea that can hold your interest, use the Topic Selection Wizard found at ScienceBuddies.org. (We will do this in class).

These are examples of bad science fair project topics that you should avoid:

Science Project Topics to Avoid	Why
Any topic that boils down to a simple preference or taste comparison. For example, "Which tastes better: Coke or Pepsi?"	Such experiments don't involve the kinds of numerical measurements we want in a science fair project. They are more of a survey than an experiment.
Most consumer product testing of the "Which is best?" type. This includes comparisons of popcorn, bubblegum, make-up, detergents, cleaning products, and paper towels.	These projects only have scientific validity if the Investigator fully understands the science behind why the product works and applies that understanding to the experiment. While many consumer products are easy to use, the science behind them is often at the level of a graduate student in college.
Any topic that requires people to recall things they did in the past.	The data tends to be unreliable.
Effect of colored light on plants	Several people do this project at almost every science fair. You can be more creative!
Effect of music or talking on plants	Difficult to measure.
Effect of running, music, video games, or almost anything on blood pressure	The result is either obvious (the heart beats faster when you run) or difficult to measure with proper controls (the effect of music).
Effect of color on memory, emotion, mood, taste, strength, etc.	Highly subjective and difficult to measure.
Any topic that requires measurements that will be extremely difficult to make or repeat, given your equipment.	Without measurement, you can't do science.
Graphology or handwriting analysis	Questionable scientific validity.
Astrology or ESP	No scientific validity.

Any topic that requires dangerous, hard to find, expensive, or illegal materials.	Violates the rules of virtually any science fair.
Any topic that requires drugging, pain, or injury to a live vertebrate animal.	Violates the rules of virtually any science fair.
Any topic that creates unacceptable risk (physical or psychological) to a human subject.	Violates the rules of virtually any science fair.
Any topic that involves collection of tissue samples from living humans or vertebrate animals.	Violates the rules of virtually any science fair.

Your Science Fair Project Question/Purpose

The question that you select for your science fair project is the cornerstone of your work. The research and experiment you will be conducting all revolve around finding an answer to the question you are posing. It is important to select a question that is going to be interesting to work on for at least a month or two and a question that is specific enough to allow you to find the answer with a simple experiment. A scientific question usually starts with: How, What, When, Who, Which, Why, or Where. Here are some characteristics of a good science fair project question:

- The question should be interesting enough to read about, then work on for the next couple months.
- There should be at least 3 sources of written information on the subject. You want to be able to build on the experience of others!

Now, for something like a science fair project, it is important to think ahead. This will save you lots of unhappiness later. Imagine the experiment you might perform to answer your question. How does that possible experiment stack up against these issues?

- The experiment should measure changes to the important factors (variables) using a number that represents a quantity such as a count, percentage, length, width, weight, voltage, velocity, energy, time, etc. Or, just as good might be an experiment that measures a factor (variable) that is simply present or not present. For example, lights ON in one trial, then lights OFF in another trial, or USE fertilizer in one trial, then DON'T USE fertilizer in another trial. If you can't measure the results of your experiment, you're not doing science!

- You must be able to control other factors that might influence your experiment, so that you can do a fair test. A “fair test” occurs when you change only one factor (variable) and keep all other conditions the same.
- Is your experiment safe to perform?
- Do you have all the materials and equipment you need for your science fair project, or will you be able to obtain them quickly and at a very low cost?
- Do you have enough time to do your experiment before the science fair? For example, most plants take weeks to grow. If you want to do a project o plants, you need to start very early! For most experiments, you will want to allow enough time to do a practice run in order to work out any problems in your procedures.
- Does your science fair project meet all the rules and requirements for your science fair?
- Have you avoided the bad science fair projects listed in the table below?

If you don’t have good answers for the above issues, then you probably should look for a better science fair project question to answer.

Some science fair projects that involve human subjects, vertebrate animals (animals with a backbone) or animal tissue, pathogenic agents, DNA, or controlled or hazardous substances, need SRC (Scientific Review Committee) approval from your science fair BEFORE you start experimentation. Now is the time to start thinking about getting approval if necessary for your science project.

Examples

These are examples of good science fair project questions:

- How does water purity affect surface tension?
- When is the best time to plant soybeans?
- Which material is the best insulator?
- What sugars do yeast use?
- How do different foundations stand up to earthquakes?

Science Fair Project Question Checklist

Here are some things to consider as you finalize your question:

What Makes a Good Science Fair Project Question?	For a Good Science Fair Project Question, You Should Answer "Yes" to Every Question
Is the topic interesting enough to read about, then work on for the next couple months?	Yes / No
Can you find at least 3 sources of written information on the subject?	Yes / No
Can you measure changes to the important factors (variables) using a number that represents a quantity such as a count, percentage, length, width, weight, voltage, velocity, energy, time, etc.? Or, just as good, are you measuring a factor (variable) that is simply present or not present? For example, • Lights **ON** in one trial, then lights **OFF** in another trial, • **USE** fertilizer in one trial, then **DON'T USE** fertilizer in another trial.	Yes / No
Can you design a "fair test" to answer your question? In other words, can you change only one factor (variable) at a time, and control other factors that might influence your experiment, so that they do not interfere?	Yes / No
Is your experiment safe to perform?	Yes / No
Do you have all the materials and equipment you need for your science fair project, or will you be able to obtain them quickly and at a very low cost?	Yes / No
Do you have enough time to do your experiment more than once before the science fair?	Yes / No
Does your science fair project meet all the rules and requirements for your science fair?	Yes / No

Have you checked to see if your science fair project will require SRC (Scientific Review Committee) approval?	Yes / No
Have you avoided the bad science fair project topic areas listed in the table above?	Yes / No

Science Fair Project Proposal Form

You will need to fill out the Science Fair Project Proposal Form. The proposal form allows you to get feedback on your science fair project from your teacher, parents, or other people you know who might give you valuable feedback.

Why do Background Research?

Key Info

Background research is necessary so that you know how to design and understand your experiment. To make a **background research plan** -- a roadmap of the research questions you need to answer -- follow these steps:

1. Identify the keywords in the question for your science fair project. Brainstorm additional keywords and concepts.
2. Use a table with the "question words" (why, how, who, what, when, where) to generate research questions from your keywords. For example:

What is the difference between a series and parallel circuit?
When does a plant grow the most, during the day or night?
Where is the focal point of a lens?
How does a java applet work?
Does a truss make a bridge stronger?
Why are moths attracted to light?
Which cleaning products kill the most bacteria?

Throw out irrelevant questions.

3. Add to your background research plan a list of mathematical formulas or equations (if any) that you will need to describe the results of your experiment.
4. You should also plan to do background research on the history of similar experiments or inventions.
5. Network with other people with more experience than yourself: your mentors, parents, and teachers. Ask them: "What science concepts should I study to better understand my science fair project?" and "What area of science covers my project?" Better yet, ask even more specific questions.
6. If you are doing an engineering project, be sure to include questions from Engineering & Programming Project Tips.

Why the Need for Background Research?

So that you can design an experiment, you need to research what techniques and equipment might be best for investigating your topic. Rather than starting from scratch, savvy investigators want to use their library and Internet research to help them find the best way to do things. You want to learn from the experience of others rather than blunder around and repeat their mistakes. A scientist named Mike Kalish put it humorously like this: "A year in the lab can save you a day in the library."

Background research is also important to help you understand the theory behind your experiment. In other words, science fair judges like to see that you understand why your experiment turns out the way it does. You do library and Internet research so that you can make a prediction of what will occur in your experiment, and then whether that prediction is right or wrong, you will have the knowledge to understand what caused the behavior you observed.

Making a Background Research Plan: How to Know What to Look For

When you are driving a car there are two ways to find your destination: drive around randomly until you finally stumble upon what you're looking for OR look at a map before you start. (Which way do your parents drive?)

Finding information for your background research is very similar. But, since libraries and the Internet both contain millions of pages of information and facts, you might never find what you're looking for unless you start with a map! To avoid getting lost, you need a background research plan.

Keywords

The place to start building your background research plan is with the question for your science fair project (see, we did that first for a reason). Let's imagine that you have asked this one:

Question: Does drinking milk help decrease spiciness better than water or Pepsi?

Begin by identifying the keywords and main concepts in your question. In this case keywords would be:

- Milk
- Spiciness
- Pepsi
- Water

That's pretty easy! Now, what might be some of the main concepts that relate to these keywords? Let's think about spiciness first. You're going to do a science experiment, so knowing that a spicy food tastes "hot" is probably not sufficient. Hmmmm, this is a little tougher than finding the keywords.

Question Words Table

The secret is to use the "question words" (why, how, who, what, when, where) with your keywords. Ask why things happen, ask how things happen, ask what causes things to happen, ask what are the properties of key substances. Filling in a little table can help. Let's do it for our keyword spiciness:

Question Word	**Fill Your Keywords (or Variations on Your Keywords) into the Blanks** ***These are just samples to get you thinking; there are always many more questions and the most important ones for your project may not be in the list!***	Possible Questions for Background Research	Relevant?
Why	Why does ________ happen? Why does ________ ________?	Why does spiciness happen? Why do spicy foods taste hot?	No Yes
How	How does ________ happen? How does ________ work? How does ________ detect ________? How does one measure ________? How do we use _________?	How does the tongue detect spiciness? How does one measure spiciness?	Yes Yes
Who	Who needs ________? Who discovered ________? Who invented ________?	Who needs spiciness?	No
What	What causes ________ to increase (or decrease)? What is the composition of _________? What are the properties and characteristics of ________? What is the relationship between _______ and ________? What do we use ________ for?	What causes spiciness to increase (or decrease)? What are the properties and characteristics of spicy substances?	Yes Yes
When	When does ________ cause ________? When was _______ discovered or invented?	When does spiciness cause upset stomachs?	No
Where	Where does ________ occur? Where do we use ________?	Where in the body does spiciness occur?	Yes

Those look like pretty good questions to research because they would enable us to make some predictions about an experiment. But what's that column in the table called "Relevant?"

You can always find more information to research, but some questions just don't have anything to do with the experiment you will define and perform. Questions that **will** help you design and understand your experiment are called *relevant*. Questions that **will not** help you design and understand your experiment are called *irrelevant*. Our table of question words is a great way to generate ideas for your background research, but some of them will be irrelevant and we just throw those out. Some of those irrelevant questions might be very interesting to you; they just don't belong as part of your science fair project. We have to focus our efforts on what we feel is most important, or another way of looking at it, let's not spend time researching anything we don't need to. (I'm sure you have other things you'd like to do, too!)

For a good example of how the question word table can generate irrelevant questions, let's just look at some possible questions if we fill out the table for another one of our sample keywords: milk.

- Why does milk happen?
- How does milk happen?
- Who needs milk?
- What causes milk to increase (or decrease)?
- What is milk composed of?
- What are the properties and characteristics of milk?
- Where does milk occur?

If we research every one of those questions we'll be studying farms, cows, cow udders, baby cows, and what cows eat. Holy flying cows! That information is definitely irrelevant to our science fair project question: Does drinking milk help decrease spiciness better than water or Pepsi?

Even so, in that crazy list of cow science, there are two questions that look relevant for your background research:

- What is milk composed of?
- What are the properties and characteristics of milk?

Sometimes you won't be sure whether a question is relevant or not, and that's always a good time to get the opinion of more experienced people like your mentors, parents, and teachers. In fact, the background research plan is a very important step of your science fair project and two or three heads are always better than one! Even with all that help, you may not be sure whether something is relevant until after you have done your experiment, so don't let it bother you if that's the case.

Talk to People with More Experience: Networking

As you can see with the two above examples, spiciness and milk, the question word table will work better for some keywords than others. You might have a science fair project question where none of the keywords generate relevant questions. Yikes! What do you do then?

One of the most important things you can do is talk to other people with more experience than yourself: your mentors, parents, and teachers. This is called "networking." Some of these people will have had classes or work experience that involved studying the science involved in your project. Ask them, "What science concepts should I study to better understand my project?" Better yet, be as specific as you can when asking your question. Even experts will look puzzled if you ask a question that is so generic it leaves them pondering where to start. Instead of asking, "How do airplanes fly," try asking, "What physical forces are involved in the flight of an airplane," or "What role do propellers play in the flight of a helicopter?" (After all, there's gotta be something that causes that hunk of metal to go up, right?)

For example, let's imagine your science fair project question is: Does the velocity of a roller coaster car affect whether it falls off a loop? If you ask someone who has studied physics in high school or college, they will tell you to ask the research question, "What is centripetal force?"

Sometimes there is even a specialized area of science that studies questions similar to the one for your science fair project. Believe it or not, there are actually people who study "roller coaster physics." (Is that a cool job or what?) Often a good topic for your background research is simply the specialized area of science that covers your project. For the roller coaster example you would research "roller coaster physics."

How do you find the area of science that covers your project? You guessed it, network with your mentors, parents, and teachers. And by the way, networking is something many adults don't expect students to be very good at, so you can probably surprise them by doing a good job at it! The very best networkers, of course, enjoy the spoils of victory. In other words, they get what they want more quickly, efficiently, and smoothly.

The reality is we have all networked at some point in our lives. Remember how you "networked" with your mom to buy you that cool water gun, or "networked" with your grandpa to buy you that video game you always wanted? Well, now you are "networking" for knowledge (which is a very good thing to network for, by the way). Train yourself to become a good networker, and you might just end up with a better science fair project (and don't forget that you'll get a little smarter too in the process). So take our advice: work hard, but network harder.

Are You Doing an Engineering or Programming Project?

If you are doing an engineering or programming project that involves designing or inventing a new device, procedure, computer program, or algorithm, then be sure to check Engineering & Programming Project Tips. You should have some special questions in your background research plan.

Sample Background Research Plan

Background research plan for the science fair project question: Does drinking milk help decrease spiciness better than water or Pepsi?

Keywords —

- Milk
- Spiciness
- Pepsi
- Water

Research questions —

- Why do spicy foods taste hot?
- How does the tongue detect spiciness?
- How does one measure spiciness?
- What causes spiciness to increase (or decrease)?
- What are the properties and characteristics of spicy substances?
- Where in the body does spiciness occur?
- What is the composition of milk, Pepsi, and water?
- What are the properties and characteristics of milk, Pepsi, and water?

Background Research Plan Checklist

What Makes a Good Background Research Plan?	For a Good Background Research Plan, You Should Answer "Yes" to Every Question
Have you identified all the keywords in your science fair project question?	Yes / No
Have you used the question word table to generate research questions?	Yes / No
Have you thrown out irrelevant questions?	Yes / No
Will the answers to your research questions give you the information you need to design an experiment and predict the outcome?	Yes / No
Do one or more of your research questions specifically ask about any equipment or techniques you will need to perform an experiment? (if applicable)	Yes / No
If you are doing an engineering or programming project, have you included questions from Engineering & Programming Project Tips?	Yes / No

What makes a good Hypothesis?

Key Info

- A hypothesis is an educated guess about how things work.
- Most of the time a hypothesis is written like this: "If _____[I do this] _____, then _____[this]_____ will happen." (Fill in the blanks with the appropriate information from your own experiment.)
- Your hypothesis should be something that you can actually test, what's called a **testable** hypothesis. In other words, you need to be able to measure both "what you do" and "what will happen."

Hypothesis

After having thoroughly researched your question, you should have some educated guess about how things work. This educated guess about the answer to your question is called the hypothesis.

The hypothesis must be worded so that it can be tested in your experiment. Do this by expressing the hypothesis using your independent variable (the variable you change during your experiment) and your dependent variable (the variable you observe-changes in the dependent variable depend on changes in the independent variable). In fact, many hypotheses are stated exactly like this: "If a particular independent variable is changed, then there is also a change in a certain dependent variable."

Example Hypotheses

- "If I open the faucet [faucet opening size is the independent variable], then it will increase the flow of water [flow of water is the dependent variable].
- "Raising the temperature of a cup of water [temperature is the independent variable] will increase the amount of sugar that dissolves [the amount of sugar is the dependent variable]."
- "If a plant receives fertilizer [having fertilizer is the independent variable], then it will grow to be bigger than a plant that does not receive fertilizer [plant size is the dependent variable]."

- "If I put fenders on a bicycle [having fenders is the independent variable], then they will keep the rider dry when riding through puddles [the dependent variable is how much water splashes on the rider]."

Note: When you write your own hypothesis you can leave out the part in the above examples that is in brackets [ ].

Notice that in each of the examples it will be easy to measure the independent variables. This is another important characteristic of a good hypothesis. If we can readily measure the variables in the hypothesis, then we say that the hypothesis is **testable**.

Not every question can be answered by the scientific method. The hypothesis is the key. If you can state your question as a testable hypothesis, then you can use the scientific method to obtain an answer.

Advanced Topic -- Cause & Effect or Correlation?

In some experiments it is not possible to demonstrate that a change in the independent variable **causes** a change in the dependent variable. Instead one may only be able to show that the independent variable is related to the dependent variable. This relationship is called a **correlation**. One of the most common reasons to see a correlation is that "*intervening* variables are also involved which may give rise to the *appearance* of a possibly direct cause-and-effect relationship, but which upon further investigation turn out to be more directly caused by some other factor" (Wikipedia, 2006).

Advanced Topic -- Is it OK to Disprove Your Hypothesis?

Is all science accomplished using this same method that is taught in schools and emphasized at science fairs? Should you worry if you end up disproving your hypothesis? Actually, the answers are no it's not, and no don't worry if you disprove your hypothesis.

Sample

Question

Which AA battery maintains its voltage for the longest period of time in low, medium, and high current drain devices?

Variables

Independent Variable: Time, how long each battery operates.

Dependent Variable: Voltage.

Experimental Group	Controlled Variables for Each Group
Low current drain	Same portable CD player Play the same music track Play at the same volume level

Medium current drain	**Identical flashlight** **Identical light bulb**
High current drain	**Same camera flash**
All groups	**Battery size (AA)** **Constant temperature (A battery works better at a warm temperature.)**

Hypothesis

Hypothesis: As I test for increasingly long periods of time, the Energizer AA battery will maintain a higher voltage than other batteries.

Hypothesis Checklist

What Makes a Good Hypothesis?	For a Good Hypothesis, You Should Answer "Yes" to Every Question
Is the hypothesis based on information contained in the Research Paper?	Yes / No
Does the hypothesis include the independent and dependent variables?	Yes / No
Have you worded the hypothesis so that it can be tested in the experiment?	Yes / No
If you are doing an engineering or programming project, have you established your design criteria?	Yes / No

What makes a good Materials List?

What type of supplies and equipment will you need to complete your science fair project? By making a complete list ahead of time, you can make sure that you have everything on hand when you need it. Some items may take time to obtain, so making a materials list in advance represents good planning!

Make the materials list as specific as possible, and be sure you can get everything you need before you start your science fair project. Visit our Supplies & Materials page for tips on places to purchase some of the harder to find items that you may have on your list.

A Good Materials List Is Very Specific	A Bad Materials List
500 ml of de-ionized water	Water
Stopwatch with 0.1 sec accuracy	Clock
AA alkaline battery	Battery

Sample

Here is a sample materials list and experimental procedure.

Materials List Checklist

What Makes a Good Materials List?	For a Good Materials List, You Should Answer "Yes" to Every Question
Have you listed all necessary materials?	Yes / No
Have you described the materials in sufficient detail?	Yes / No

How do I write a good Procedure?

Key Info

- Write the **experimental procedure** like a step-by-step recipe for your science experiment. A good procedure is so detailed and complete that it lets someone else duplicate your experiment exactly!
- **Repeating a science experiment is an important step** to verify that your results are consistent and not just an accident.
    - For a typical experiment, you should plan to repeat it at least three times (more is better).
    - If you are doing something like growing plants, then you should do the experiment on at least three plants in separate pots (that's the same as doing the experiment three times).
    - If you are doing an experiment that involves testing or surveying different groups, you won't need to repeat the experiment three times, but you will need to test or survey a sufficient number of participants to insure that your results are reliable. You will almost always need many more than three participants! See our Science Buddies resource, How Many Survey Participants Do I Need?

Overview

Now that you have come up with a hypothesis, you need to develop an experimental procedure for testing whether it is true or false.

The first step of designing your experimental procedure involves planning how you will change your independent variable and how you will measure the impact that this change has on the dependent variable. To guarantee a fair test when you are conducting your experiment, you need to make sure that the only thing you change is the independent variable. And, all the controlled variables must remain constant. Only then can you be sure that the change you make to the independent variable actually caused the changes you observe in the dependent variables.

Scientists run experiments more than once to verify that results are consistent. In other words, you must verify that you obtain essentially the same results every time you repeat the experiment with the same value for your independent variable. This insures that the answer to your question is not just an accident. Each time that you perform your experiment is called a **run** or a **trial**. So, your experimental procedure should also specify how many trials you intend to run. Most teachers want you to **repeat your experiment a minimum of three times**. Repeating your experiment more than three times is even better, and doing so may even be required to measure very small changes in some experiments.

In some experiments, you can run the trials all at once. For example, if you are growing plants, you can put three identical plants (or seeds) in three separate pots and that would count as three trials.

In experiments that involve testing or surveying different groups of people, you will not need to repeat the experiment multiple times. However, in order to insure that your results are reliable, you need to test or survey enough people to make sure that your results are reliable. How many participants are enough, what is the ideal sample size? See the Science Buddies resource, How Many Survey Participants Do I Need?, to find out.

Every good experiment also **compares** different groups of trials with each other. Such a comparison helps insure that the changes you see when you change the independent variable are in fact caused by the independent variable. There are two types of trial groups: experimental groups and control groups.

The **experimental group** consists of the trials where you change the independent variable. For example, if your question asks whether fertilizer makes a plant grow bigger, then the experimental group consists of all trials in which the plants receive fertilizer.

In many experiments it is important to perform a trial with the independent variable at a special setting for comparison with the other trials. This trial is referred to as a **control group**. The control group consists of all those trials where you leave the independent variable in its natural state. In our example, it would be important to run some trials in which the plants get no fertilizer at all. These trials with no fertilizer provide a basis for comparison, and would insure that any changes you see when you add fertilizer are in fact caused by the fertilizer and not something else.

However, not every experiment is like our fertilizer example. In another kind of experiment, many groups of trials are performed at different values of the independent variable. For example, if your question asks whether an electric motor turns faster if you increase the voltage, you might do an experimental group of three trials at 1.5 volts, another group of three trials at 2.0 volts, three trials at 2.5 volts, and so on. In such an experiment you are comparing the experimental groups to each other, rather than comparing them to a single control group. You must evaluate whether your experiment is more like the fertilizer example, which requires a special control group, or more like the motor example that does not.

Whether or not your experiment has a control group, remember that every experiment has a number of controlled variables. Controlled variables are those variables that we don't want to change while we conduct our experiment, and they must be the same in every trial and every group of trials. In our fertilizer example, we would want to make sure that every trial received the same amount of water, light, and warmth. Even though an experiment measuring the effect of voltage on the motor's speed of rotation may not have a control group, it still has controlled variables: the same motor is used for every trial and the load on the motor (the work it does) is kept the same.

A little advance preparation can ensure that your experiment will run smoothly and that you will not encounter any unexpected surprises at the last minute. You will little advance preparation can ensure that your experiment will run smoothly and that you will not encounter any unexpected surprises at the last minute. You will need to prepare a detailed experimental procedure for your experiment so you can ensure consistency from beginning to end. Think about it as writing a recipe for your experiment. This also makes it much easier for someone else to test your experiment if they are interested in seeing how you got your results.

Key Elements of the Experimental Procedure

- Description and size of all experimental and control groups, as applicable
- A step-by-step list of everything you must do to perform your experiment. Think about all the steps that you will need to go through to complete your experiment, and record exactly what will need to be done in each step.
- The experimental procedure must tell how you will change your one and only independent variable and how you will measure that change
- The experimental procedure must explain how you will measure the resulting change in the dependent variable or variables
- If applicable, the experimental procedure should explain how the controlled variables will be maintained at a constant value
- The experimental procedure should specify how many times you intend to repeat your experiment, so that you can verify that your results are reproducible.
- A good experimental procedure enables someone else to duplicate your experiment exactly!

Where will you conduct your experiment? You may need a lot of room for you experiment or you may not be able to move your experiment around from place to place. If you are working with human or animal subjects, you may need a location that is quiet. You will need to think about these limitations before you start your experiment so you can find a location in advance that will meet your needs.

Experimental Procedure Checklist

What Makes a Good Experimental Procedure?	**For a Good Experimental Procedure, You Should Answer "Yes" to Every Question**
Have you included a description and size for all experimental and control groups?	Yes / No
Have you included a step-by-step list of all procedures?	Yes / No
Have you described how to the change independent variable and how to measure that change?	Yes / No
Have you explained how to measure the resulting change in the dependent variable or variables?	Yes / No
Have you explained how the controlled variables will be maintained at a constant value?	Yes / No

Have you specified how many times you intend to repeat the experiment (should be at least three times), and is that number of repetitions sufficient to give you reliable data?	Yes / No
The ultimate test: Can another individual duplicate the experiment based on the experimental procedure you have written?	Yes / No
If you are doing an engineering or programming project, have you completed several preliminary designs?	Yes / No

What makes a good graph?

Key Info

- **Review** your data. Try to look at the results of your experiment with a critical eye. Ask yourself these questions:
  - Is it complete, or did you forget something?
  - Do you need to collect more data?
  - Did you make any mistakes?
- **Calculate an average** for the different trials of your experiment, if appropriate.
- **Make sure to clearly label** all tables and graphs. And, include the **units of measurement** (volts, inches, grams, etc.).
- Place your **independent variable on the x-axis** of your graph and the **dependent variable on the y-axis**.

Overview

Take some time to carefully review all of the data you have collected from your experiment. Use charts and graphs to help you analyze the data and patterns. Did you get the results you had expected? What did you find out from your experiment?

Really think about what you have discovered and use your data to help you explain why you think certain things happened.

Calculations and Summarizing Data

Often, you will need to perform calculations on your raw data in order to get the results from which you will generate a conclusion. A spreadsheet program such as Microsoft Excel may be a good way to perform such calculations, and then later the spreadsheet can be used to display the results. Be sure to label the rows and columns--don't forget to include the units of measurement (grams, centimeters, liters, etc.).

You should have performed multiple trials of your experiment. Think about the best way to summarize your data. Do you want to calculate the average for each group of trials, or summarize the results in some other way such as ratios, percentages, or error and significance for really advanced students? Or, is it better to display your data as individual data points?

Do any calculations that are necessary for you to analyze and understand the data from your experiment.

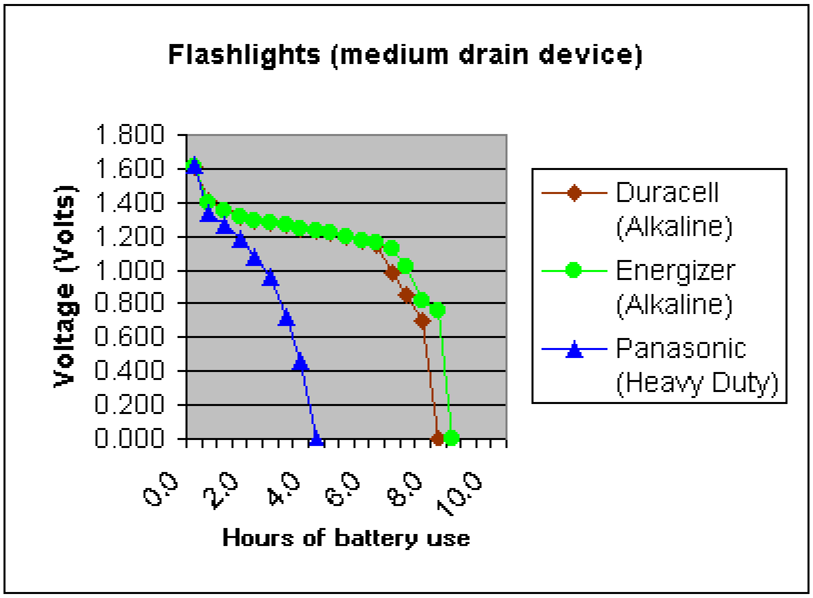
- Use calculations from known formulas that describe the relationships you are testing. (F = MA , V = IR or E = MC2)
- Pay careful attention because you may need to convert some of your units to do your calculation correctly. All of the units for a measurement should be of the same scale– (keep L with L and mL with mL, do not mix L with mL!)

Graphs

Graphs are often an excellent way to display your results. In fact, most good science fair projects have at least one graph.

For any type of graph:

- Generally, you should place your independent variable on the x-axis of your graph and the dependent variable on the y-axis.
- Be sure to label the axes of your graph— don't forget to include the units of measurement (grams, centimeters, liters, etc.).
- If you have more than one set of data, show each series in a different color or symbol and include a legend with clear labels.



Different types of graphs are appropriate for different experiments. These are just a few of the possible types of graphs:

A **bar graph** might be appropriate for comparing different trials or different experimental groups. It also may be a good choice if your independent variable is not numerical. (In Microsoft Excel, generate bar graphs by choosing chart types "Column" or "Bar.")

A **time-series** plot can be used if your dependent variable is numerical and your independent variable is time. (In Microsoft Excel, the "line graph" chart type generates a time series. By default, Excel simply puts a count on the x-axis. To generate a time series plot with your choice of x-axis units, make a separate data column that contains those units next to your dependent variable. Then choose the "XY (scatter)" chart type, with a sub-type that draws a line.)

An **xy-line graph** shows the relationship between your dependent and independent variables when both are numerical and the dependent variable is a function of the independent variable. (In Microsoft Excel, choose the "XY (scatter)" chart type, and then choose a sub-type that does draw a line.)

A **scatter plot** might be the proper graph if you're trying to show how two variables may be related to one another. (In Microsoft Excel, choose the "XY (scatter)" chart type, and then choose a sub-type that does not draw a line.)

Sample

Here is a sample Excel spreadsheet that contains data analysis and a graph.

Data Analysis Checklist

What Makes for a Good Data Analysis Chart?	For a Good Chart, You Should Answer "Yes" to Every Question
Is there sufficient data to know whether your hypothesis is correct?	Yes / No
Is your data accurate?	Yes / No
Have you summarized your data with an average, if appropriate?	Yes / No
Does your chart specify units of measurement for all data?	Yes / No
Have you verified that all calculations (if any) are correct?	Yes / No

Graph Checklist

What Makes for a Good Graph?	For a Good Graph, You Should Answer "Yes" to Every Question
Have you selected the appropriate graph type for the data you are displaying?	Yes / No
Does your graph have a title?	Yes / No
Have you placed the independent variable on the x-axis and the dependent variable on the y-axis?	Yes / No

Have you labeled the axes correctly and specified the units of measurement?	Yes / No
Does your graph have the proper scale (the appropriate high and low values on the axes)?	Yes / No
Is your data plotted correctly and clearly?	Yes / No

How do I write a good conclusion?

Key Info
Your **conclusions** summarize how your results support or contradict your original hypothesis:

- Summarize your science fair project results in a few sentences and use this summary to support your conclusion. Include key facts from your background research to help explain your results as needed.
- State whether your results support or contradict your hypothesis. (Engineering & programming projects should state whether they met their design criteria.)
- If appropriate, state the relationship between the independent and dependent variable.
- Summarize and evaluate your experimental procedure, making comments about its success and effectiveness.
- Suggest changes in the experimental procedure (or design) and/or possibilities for further study.

Overview

Your conclusions will summarize whether or not your science fair project results support or contradict your original hypothesis. If you are doing an Engineering or Computer Science programming project, then you should state whether or not you met your design criteria. You may want to include key facts from your background research to help explain your results. Do your results suggest a relationship between the independent and dependent variable?

If Your Results Show that Your Hypothesis is False

If the results of your science experiment did not support your hypothesis, don't change or manipulate your results to fit your original hypothesis, simply explain why things did not go as expected. Professional scientists commonly find that results do not support their hypothesis, and they use those unexpected results as the first step in constructing a new hypothesis. If you think you need additional experimentation, describe what you think should happen next.

Scientific research is an ongoing process, and by discovering that your hypothesis is not true, you have already made huge advances in your learning that will lead you to ask more questions that lead to new experiments. Science fair judges do not care about whether you prove or disprove your hypothesis; they care how much you learned.

Conclusions Checklist

What Makes for Good Conclusions?	For Good Conclusions, You Should Answer "Yes" to Every Question
Do you summarize your results and use it to support the findings?	Yes / No
Do your conclusions state that you proved or disproved your hypothesis? (Engineering & programming projects should state whether they met their design criteria.)	Yes / No
If appropriate, do you state the relationship between the independent and dependent variable?	Yes / No
Do you summarize and evaluate your experimental procedure, making comments about its success and effectiveness?	Yes / No
Do you suggest changes in the experimental procedure and/or possibilities for further study?	Yes / No

Science Fair Project Final Report Checklist

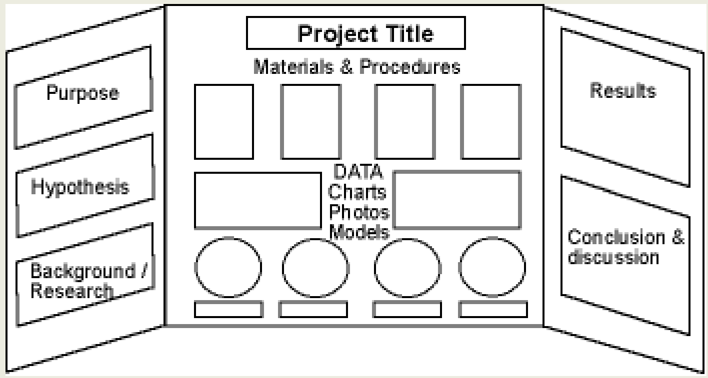
What Makes for a Good Science Fair Project Final Report?	For a Good Science Fair Project Final Report, You Should Answer "Yes" to Every Question
Does your final report include: • Title page. • Abstract. • Table of contents. • Question, variables, and hypothesis. • Background research. • Materials list. • Experimental procedure. • Data analysis and discussion (including data table and graph(s)). • Conclusions.	Yes / No

- Bibliography.

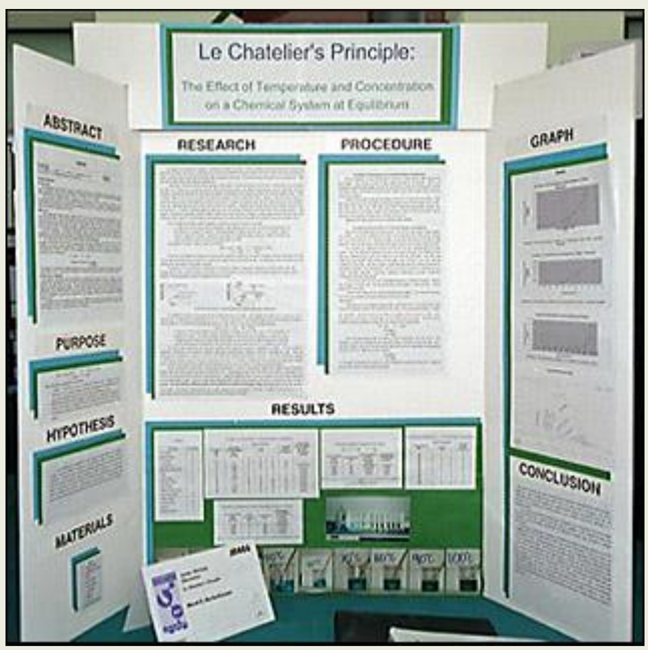
What goes on my display board?

Key Info

- For almost every science fair project, you need to prepare a **display board** to communicate your work to others. In most cases you will use a standard, three-panel display board that unfolds to be 36" tall by 48" wide.



- **Organize your information like a newspaper** so that your audience can quickly follow the thread of your experiment by reading from top to bottom, then left to right. Include each step of your science fair project: Abstract, question, hypothesis, variables, background research, and so on.



- **Use a font size of at least 16 points** for the text on your display board, so that it is easy to read from a few feet away. It's OK to use slightly smaller fonts for captions on picture and tables.
- **The title should be big and easily read from across the room**. Choose one that accurately describes your work, but also grabs peoples' attention.
- **A picture speaks a thousand words!** Use photos or draw diagrams to present non-numerical data, to propose models that explain your results, or just to show your experimental setup. But, don't put text on top of photographs or images. It can be very difficult to read.

This sample shows how difficult it can be to read text when you print it on top of an image. Don't do it!

- **Check the rules for your science fair.** Here is a list of items that some science fairs allow (or even require) and some science fairs don't require (or even prohibit):
  - Your name on the display board
  - Pictures of yourself
  - Captions that include the source for every picture or image
  - Acknowledgements of people who helped you
  - Your laboratory notebook (some science fairs want you to have it only during judging)
  - Equipment such as your laboratory apparatus or your invention

Materials and Construction Techniques

- The standard presentation boards are self-standing and work quite well. Display boards in black or white-colored "foam core" (a sandwich made up of two pieces of cardboard with plastic foam in the middle) or corrugated cardboard are readily available at most office supply stores (Staples, Office Depot, Office Max) for $6 to $12. Of course, you can also make your own for free from a large cardboard box.

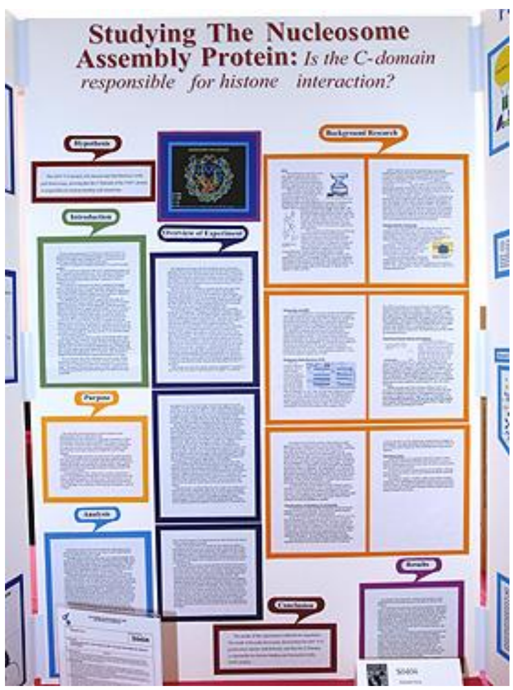
- Print out or write your information on white paper that you will attach to your display board. Be sure to proofread each sheet before you attach it.

- Glue sticks (use plenty) work well for attaching sheets of paper to your display board. Use double-sided tape for items like photographs that may not stick to glue.

Use glue sticks for attaching paper to your board. Double-sided tape is good for attaching photographs.

- Tip: Instead of regular paper, use cover stock (67#) or card stock (110#). These heavier papers will wrinkle less when you attach it to your display board, especially if you use a glue stick. Matte paper is preferable to glossy because it won't show as much glare— glare makes your display board difficult to read.

- Use color construction paper to add accents to your display board. A common technique is to put sheets of construction paper behind the white paper containing your text.



Color construction paper can accent your board.

Science Fair Project Display Board Checklist

What Makes for a Good Science Fair Project Display Board?	For a Good Science Fair Project Display Board, You Should Answer "Yes" to Every Question
Does your display board include: • Title • Question • Variables and hypothesis • Background research • Materials list • Experimental procedure • Data analysis and discussion including data chart(s) & graph(s) • Conclusions (including ideas for future research) • Bibliography	Yes / No
Are the sections on your display board organized like a newspaper so that they are easy to follow?	Yes / No
Is the text font large enough to be read easily (at least 16 points)?	Yes / No
Does the title catch people's attention, and is the title font large enough to be read from across the room?	Yes / No
Did you use pictures and diagrams to effectively convey information about your science fair project?	Yes / No
Have you constructed your display board as neatly as possible?	Yes / No
Did you proofread your display board?	Yes / No
Did you follow all of the rules pertaining to display boards for your particular science fair?	Yes / No