Massachusetts State Science & Engineering Fair

Student Guide:
How to Do a Science Fair Project

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1.0 WHY DO A SCIENCE FAIR PROJECT?

What do market analysts, forensic crime technicians, and backyard gardeners have in common? They all apply the inquiry process to the research necessary in their careers. Most professions have common skills that are required for success, such as critical and creative thinking involving gaining, applying, and communicating knowledge. Working collaboratively and contributing are common themes in education, science, and technology. These common themes involve habits of mind such as curiosity, open-mindedness balanced with skepticism, a sense of stewardship and care, respect for evidence, and persistence. All these skills and themes are integral parts of doing a science fair project and help to prepare you for a changing technological world.

Working on a science fair project requires using the skills gained in Social Studies, English, Math, Technology, the Arts, and the Sciences, making a science fair project an interdisciplinary activity. Science fair projects provide opportunities to collaborate with many teachers, especially in Math and English, and implement cross-curriculum, or team leadership and cooperation.

A science fair project allows you to pose your own question and answer it. Doing a science fair project involves developing and "owning" the question; researching literature; forming a hypothesis; designing an experiment; gathering and organizing the data; analyzing, graphing, and discussing the data; making a conclusion; writing the literary and research reports; and making an oral and visual presentation. Therefore, you develop and apply skills in literary and laboratory research, statistical analysis, and public speaking, while gaining a sense of empowerment and building self-esteem. Because science fair projects are actually cross-curriculum projects that train you for real-life problem solving, the science fair project integrates all aspects of your education and helps to prepare you for real-world job assignments. Having completed a science fair project, you will have the skills necessary to design future investigations in a variety of different fields. A science fair project may become the impetus for a future career.

Science fair projects are fun and filled with self-discovery. When beginning the process, you may feel overwhelmed at its enormity, however you will experience tremendous growth and fulfillment as you progress through the steps and are evaluated by peers, teachers, and judges. This experience builds self-confidence and often enables you to present ideas to others in various situations, such as college and job interviews.

2.0 WHAT IS A SCIENCE FAIR PROJECT?

A science fair project is simply your independent research of a science topic using the scientific method. All work and ideas are yours, giving you "ownership" of the research problem and results. By doing a science fair project, you will find yourself doing the job of a practicing, professional scientist; giving you a taste of how the body of knowledge we call science is accumulated.

2.1 STEPS TO DOING A SCIENCE FAIR PROJECT

1. Get a bound notebook to use as a logbook and number the pages.
2. Select a topic.
3. Narrow the topic to a specific problem, stated as a research question, with a single variable.
4. Conduct a literature review of the topic and problem and write a draft of the research report.
5. Form a hypothesis or state the purpose of the research.
6. Develop a research plan/experimental design.
7. Apply for approval. Fill out appropriate forms and get signatures of approval.
8. Write the research report.
9. Collect materials and equipment. Make a lab schedule.
10. Conduct the experiment. Record the quantitative and qualitative data.
11. Analyze data, applying appropriate statistics.
12. Repeat your experiment, as necessary, to thoroughly explore the problem.
13. Form a conclusion.
14. Write the laboratory report.
15. Write the abstract.
16. Create the visual display.
17. Make an oral presentation of the project to teacher and/or classmates.
18. Review and polish presentation and display for the science fair.

2.2 STEPS TO DOING AN ENGINEERING PROJECT AND SOME COMPUTER PROJECTS

Engineering Projects differ from most research projects. For an engineering project you still need to have a log and do a literature search. However, the steps in the project might be as follows:

1. Define a need.
2. Develop the design criteria.
3. Do a literature search to see what has already been done.
4. Prepare preliminary designs or algorithm (flow chart).
5. Build a prototype or write program.
6. Test the prototype/program.
7. Retest and redesign, as necessary.

THE ENGINEERING PROJECT GOAL is to build a device or design a system to solve a problem.

THE COMPUTER PROJECT GOAL is to solve a problem by writing a computer program or designing a computer system.

3.0 SELECTING A TOPIC

There are several factors that need to be considered when selecting a topic. Often, the simplest of projects present the greatest challenges to an imaginative and intelligent student.

Consider the following guidelines when selecting the topic of your research project:

Choose a topic that interests you.

- A hobby such as music, gardening, or model rocketry, might give you something to investigate.
- Sometimes your interest in a sport can provide ideas for a science fair project.
- Magazine or newspaper articles on science-related events can spark your interest.
- Find out if there is a sizable amount of information and equipment available pertaining to the selected topic.
- Science-based websites may inspire ideas.

Determine if the project is feasible.

- Can the project be completed within the amount of time allowed? Have you considered the time needed for retrials or repeats of the experiment? For example, in plant projects, you will need a large sample of plants ready to go in two- or three-week intervals.
- Are there environmental concerns? For example, is it the right time of year to make your observations or collect samples?
- Do you have adequate laboratory resources or natural resources, or both, to carry out your investigation?
- What is the cost of completing the project? Is it within your budget? Do you need special equipment beyond what is available? How will you get it? Have you budgeted for retrials?
- Is the design of the experiment adequate? Are the effects measurable in an objective way?
- Does the project conform to **ALL** state or federal laws pertaining to scientific research? (See the current MSSEF Manual, Forms, and Safety Regulations)

DO YOU HAVE ENOUGH INFORMATION?

Information Sources
Before deciding on a topic, check these sources of information:

- Libraries (school, public, and college)
- Previous projects you or others have done
- Students who have already completed science fair projects (see MSSEF abstract booklets)
- Local college or scientific institution support (for information, equipment, and facilities)
- Local research firms
- Verifiable Internet Sources

Finding Ideas for Projects
You may find ideas for a science fair project from many varied sources, such as those listed here:

- Science books
- Science lab manuals
- Science fair books
- Encyclopedias
- Science periodicals
- Science teachers
- Newspaper
- Educational TV
- Science museums
- Professionals
- Consumer Reports

Complete the necessary documentation for your project.

- Some documentation will require paperwork completed both ***before*** and ***after*** experimentation for all projects.

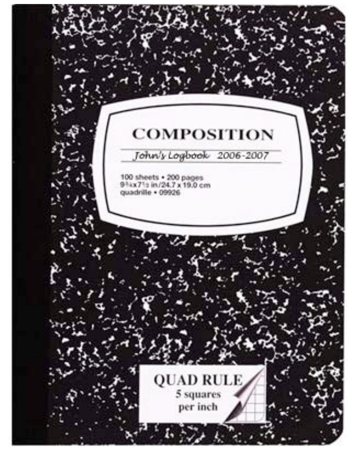
- If you chose to work with any of the materials or organisms listed below, you will need to obtain approval from the MSSEF Scientific Review Committee (SRC) ***before*** experimentation begins.
    - **Potentially Hazardous Biological Agents** (microorganisms, rDNA, human and vertebrate animal tissue, blood, body fluids, etc.)
    - **Vertebrate Animals**
    - **Human Subjects**
    - **Hazardous Chemicals, Activities or Devices**
    - **Controlled Substances**

Obtaining approval involves additional certifications, permissions, and other paperwork. This work is necessary for your protection, the protection of the environment, and certifies that you have treated animals, including humans, properly, and have adhered to the laws of your local town, state and the nation. Are you willing to complete this additional paperwork in order to work in restricted areas?

If you are continuing a project, document new and different research (e.g., testing a new variable requiring a new hypothesis).

- Repeating previous experiments or increasing sample sizes are not acceptable continuation projects.
- A Student Checklist (1A), Research Plan, Form 1, Form 1B and Continuation Form (7) need to be completed for each year's work of a continuing research project before experimentation begins.
- If you plan to work on your project over the summer, you must complete your Student Checklist and Research Plan and any other required forms, and have your school approve your paperwork before the school year ends. If you are attending a summer institute or science-training program you must have a teacher, a qualified scientist, and the MSSEF Scientific Review Committee approve the research plan before the actual training at the institute or program begins. Again, your next year's science teacher must approve your paperwork before school ends!
- Do not discard ANY of your certification forms from previous years' work when continuing a research project. You will be required to submit these forms along with the current year's forms when registering for the fair.
- Use a new logbook to mark the beginning of your continuation project. Judges are asked to evaluate your project on the merits of research completed during the current year and not on material presented at previous science fairs.

4.0 KEEPING A SCIENTIFIC NOTEBOOK OR LOG



One of the most important aspects of doing a science fair project is documentation. Every experiment should be reproducible and the entries in your notes should be sufficient for someone else to reproduce the experiment.

The first thing to do when beginning a science fair project is to get the notebook. You will work out your thinking and the development of your problem in the notebook. The scientific notebook is a bound or spiral book with pages that are not removable. The validity of your documentation partly depends upon insuring the work has not been tampered with or pages removed.

When preparing the notebook there are several things that need to be done.

1. Write your name inside the front cover.
2. Every page in the notebook must be numbered from the start. If the book pages are not already numbered, number every page in order at the upper corner along the outside edge of the pages.
3. Divide the book into sections and start a table of contents. Successful students typically divide their logbook into at least four sections (see box).
    a. In the first section, begin your quest for ideas by listing topics or problems that you might investigate, and your thoughts about each.
    b. Make a section of the notebook for literary research. For each literary research session, write the name of the library, the date, and the time visited at the top of a new page. List the resources you examine. If you take notes from a text, head the notes with all the information you will need to make a citation. Use the margins to enter the page of the reference from which the notes were taken. This will give you easy access to the "who," "what," "where," and "when" that you'll need when writing your research paper.
    c. The next section contains experimental research or engineering design including the research plan, data collection, and data analysis.
    d. The last section is the daily log where daily activities related to the research project are recorded. After the experiment is recorded, head a new page with "Discussion" or "Interpretation" before writing your inferences. Start a new page to write the "Conclusion." Remember, the better the records you keep, the easier it is to validate your work.
4. When making a new entry, begin on a new page. Date each page as you use it.
5. The notebook must include all the steps of the scientific method, from the inception of the project to its completion. Scientific notebooks include literary and experimental research, the development of your idea or product and its evaluation, and all calculations. Entries made by people other than you must be signed and dated by those people.
6. You can keep a log or daily journal in a section of your scientific notebook, or in a separate book. If you plan to use a separate book for your log or daily journal, use the

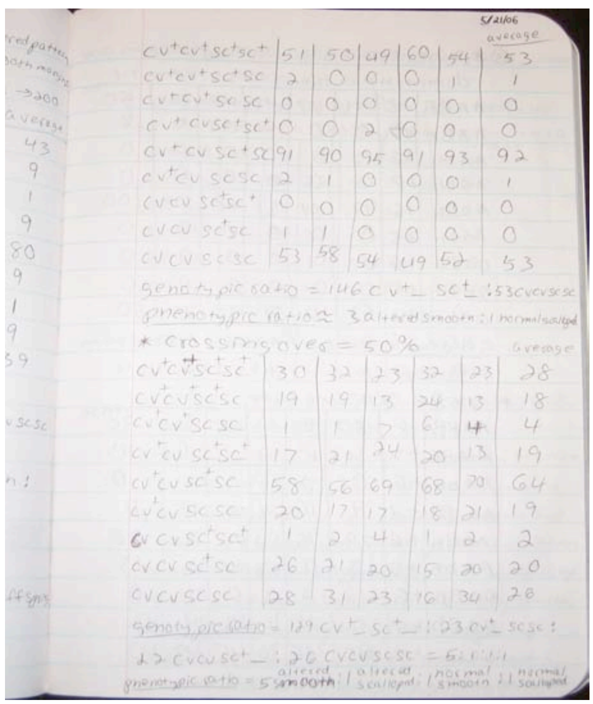
Suggested Table of Contents for a Logbook:

⌘ Choosing a Project
⌘ Literary Research
⌘ Experimental Research
⌘ Daily Log

same type of bound book. The logbook is the chronological record of events during the experimentation.

When making entries in your notebook, follow these guidelines.

- Write the entry immediately after the work was performed.
- Write the date of the entry at the top of the outside margin of every page.
- Sign and date every entry.
- Mark and title each section clearly.
- Write legibly and in clear, understandable language.
- Use the active voice in the first person when making an entry so it clearly indicates who did the work. Your experimental entries should read like a story. Illustrate as necessary - a picture can be worth a thousand words!
- Record everything - no detail is insignificant.
- Title, label, and date all graphs and tables.
- Tape, staple, or paste computer print-outs, photographs, etc. into logbook.
- Have anyone who witnesses your work sign as a witness and date the entry.
- Never remove or obliterate an entry from your notebook. What you think is “a goof” may later turn out to be to be a great asset!



5.0 RESEARCHING THE TOPIC

You have decided upon a topic and are thinking, "Where do I begin?" The best place to begin is the library. The library will have magazines, newspapers, books on the subject, scientific references, and electronic resources, each with information about some aspect of your topic.

You may think you should begin with an encyclopedia. Encyclopedias are quick references that will give you basic background information, but not the specific scientific information you may need, especially if you chose a cutting-edge field of science. It is acceptable to begin with an encyclopedia for key terms, but do not use general encyclopedias as the only source of your information, and do not include them in your list of references. However, good scientific encyclopedias, such as The Encyclopedia of Chemical Technology, are acceptable resources.

You're more likely to find what you need in large public libraries and college libraries. Scientific journals can be found at these libraries. Articles in scientific journals have some of the most up-to-date information on many current hot topics in research. There are scientific journals specific to every field in science. Articles in journals will be found in three forms: as complete papers with short abstracts, as final notes on projects, and as updates or communications about ongoing research.

Periodicals

Many popular newsstand magazines written for the general public may not have scientifically reliable information appropriate for your background research, so these should not be your main references. Some reliable periodicals for scientific research are listed below.

Air and Space Magazine
American Biology Teacher
American Journal of Physics
Astronomy
Chemical and Engineering News
Discover
Environmental Science Technology
Journal of Chemical Education
Natural History
Science
Science News
Scientific American

You will be able to find texts on particular science topics in the 500s and 600s of the library stacks. College texts have information that goes beyond what most high school texts offer. Most libraries have databases on computers, which make the search for books and magazine articles much easier.

The Internet is also a valuable tool for students doing research. When conducting research on the Internet, make sure that you use reliable sources. Information you use will need the same citation data as a book or magazine article: author, title, publisher, and copyright. It is best to download copies of everything you use, including the website address.

Remember, good literary research and documentation provides a solid foundation for your hypothesis and experiment.

Note-Taking Alternative

Some students find it useful to use note cards to record research and bibliography information in addition to recording this information in the scientific notebook. These cards can be arranged and rearranged to help you find the best sequence to present the literature and experiment. (Use a different color for each book, for easy recognition.)

6.0 FORMING A HYPOTHESIS OR STATING THE PURPOSE

Once you have selected and researched your topic, you will need to identify the problem. Phrase your problem as a question and phrase your hypothesis as a statement. Be specific in stating your hypothesis or purpose, but don't be overly wordy. Most scientists prefer a hypothesis rather than a statement of purpose, although for engineering projects or computer projects a statement of purpose is preferred.

6.1 HYPOTHESIS

A hypothesis is a trial solution to a research problem. The data you acquire through experimentation can be used to support or refute the hypothesis. Sometimes your data shows the hypothesis to be incorrect, but this is not a problem as long as your background research justifies the hypothesis. Sometimes your data will neither support nor refute your hypothesis.

Sample Hypotheses

- The ingestion of caffeine increases the heart rate of *Daphnia sp.*
- Ascorbic acid concentration in orange juice varies directly with temperature.
- Hard materials are more effective at reducing sound levels than soft materials.
- Radish seeds will not germinate as well when watered with acidic water compared with neutral water.
- Juvenile horseshoe crabs prefer a mud bottom to a sand bottom.

6.2 STATEMENT OF PURPOSE

Some project work is best summarized with a statement of purpose. This is especially true with computer or engineering projects. Rather than testing a supposition, these projects often involve the development of new equipment, materials, procedures, or models.

Sample Statements of Purpose

- The purpose of this computer program is to model the flow of various chemicals through the soil and into the ground water.
- The purpose of this project is to develop a Remotely Piloted Vehicle (RPV) that uses the cellular telephone network as a transmission system.

7.0 EXPERIMENTAL DESIGN OR RESEARCH PLAN

Enter all your design ideas and modifications in your logbook. Labeled diagrams or schematics are a good way to present your ideas. These are essential in an engineering project. With computer projects, include algorithms or flow charts.

When developing your experimental design you should consider the following questions.

- Will your design test your hypothesis or achieve your purpose?
- What variables affect your experiment? What quantity are you testing for (dependent variable) and on what does this variable depend (independent variable)? It is important to test only one variable at a time and keep other variables that might affect your results to a minimum. Keeping extraneous variables to a minimum is not always easy to achieve.

Steps of the Experimental Design/Research Plan

- Variables- Independent/Dependent
- Control Set-up
- Replication
- Material availability/cost
- Where experiment will be conducted
- Protocol (Research Plan)
- Safety concerns

7.1 VARIABLES

Independent Variable: The quantity that you vary systematically. This variable is plotted on the x-axis. The successive increments in the independent variable are often consistent. In physics projects, time is frequently the independent variable.

Example: When measuring the speed of a runner over time, time is the independent variable. Speed is the dependent variable.

Dependent Variable: This quantity changes as a result of your manipulations and depends on the independent variable. The dependent variable is plotted on the y-axis.

7.2 CONTROL SET-UP

With a few exceptions, you will need to include a control set-up as well as an experimental set-up in your experimental design. The control and experimental set-ups are exactly the same except that the control set-up does not contain the independent variable.

Example: To test the hypothesis that plants grow better in green light than in regular light, the experimental set-up would include plants grown in green light and watered and fertilized in the same way as plants grown in regular light (the control). All other variables, such as type of soil, the amount of humidity, the air temperature, and the light exposure are kept the same for both the experimental set-up and the control set-up.

7.3 REPLICATION

The more times you repeat an experiment and obtain the same results, the more statistically valid are your results. With plant projects you should plan to have at least 24 plants in your experimental group and 24 in your control group. Ideally your whole experiment should be repeated several times. Most student scientific work produces data samples that are best analyzed using a t distribution (n>30, where n is the number of samples).

Will the materials you need to perform your experiment be available?
Are they within your budget?

7.4 SCIENTIFIC PROTOCOL

Did you complete all required paperwork? (See MSSEF Manual - Research and Safety Regulations)

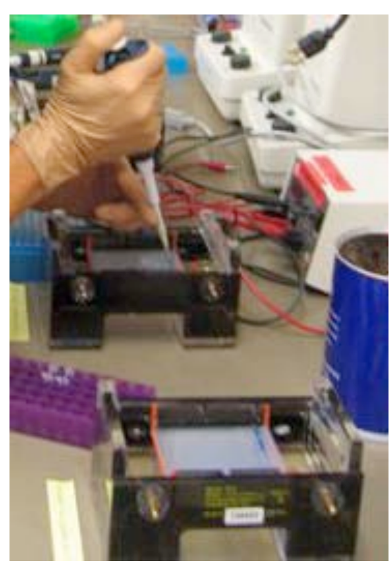
All projects are required to have a Student Checklist (1A), Research Plan, Form 1, and Form 1B, including dates and signatures, completed before experimentation begins. If you chose to work with any of the following you will need to obtain approval from the MSSEF Scientific Review Committee (SRC) before experimentation begins. This involves additional certifications, permissions and other paperwork. Experiments dealing with human subjects also require approval from an Institutional Review Board (IRB).

- **Potentially Hazardous Biological Agents** (microorganisms, rDNA, human and vertebrate animal tissue, blood, body fluids, etc.)
- **Vertebrate Animals**
- **Human Subjects**
- **Hazardous Chemicals, Activities or Devices**
- **Controlled Substances**

See MSSEF website for all necessary forms.

7.5 SAFETY MANDATES

Any experiment that involves hazardous chemicals, activities or devices (including controlled substances), potentially hazardous biological agents (including all soil and bacteria projects), and vertebrate animals will need to be performed under supervision at school or in a professional lab under the direction of a supervising scientist. This will require additional paperwork *before* experimentation begins. Working with a professional mentor or in a professional lab setting requires additional paperwork both *before* and *after* experimentation (see MSSEF Manual - Research and Safety Regulations).



8.0 CONDUCTING THE EXPERIMENT

Once your experimental design is complete, it is the time to perform the experiment. Plan and organize the experiment. Perform the experiment under controlled conditions. Keep careful records in the bound scientific notebook. The notebook is for your records and notes. If anyone else writes in it, have that person sign and date his or her entry.

Document everything you do, whether talking to a person about the project, visiting a library for research, or doing the lab work.

8.1 BEFORE YOU START YOUR EXPERIMENT

Organize all material and equipment to be ready for use as you need them. Organizing your work before starting is important.

Outline the procedure and make a timeline. An outline of the proposed timeline to complete each part of the experimentation is helpful.

- Can the entire experiment be completed at one time? Are multiple time slots needed for completion of experimentation? If so, what plans need to be made for securing materials between the experimentation sessions?
- What do you need to measure results? Are the measuring devices in metric units? Do you know how to read them? Do the instruments give accurate measurements?
- Do you need other people with you while doing the experimentation? Have you talked to those people about scheduling an appointment at a time convenient for everyone involved so that the experimentation can be carried out?

Keep your scientific notebook/log and graph paper handy. Design and set up the tables and graphs you expect to use prior to starting your experimentation. Include units where appropriate.

Keep a camera on location. The camera is a useful tool for documenting your project. Have another person take photos of you performing the experiment, and use the camera to record the progress and the results of experimentation.

Complete all certification forms and compliance forms. Make certain you have completed the Research Plan and all necessary forms for restricted areas and obtained proper approvals *before* experimentation begins.

Observe safety rules. Cover safety issues with your teacher and, if appropriate, with the research scientist and/or lab instructor at a research facility. Do not use any equipment that is unfamiliar to you; learn to use it before beginning the experiment.

8.2 BEGIN EXPERIMENTATION

Make entries in your scientific notebook as you go. Record data, both quantitative and qualitative, in your logbook. Sometimes what appears to be irrelevant or a failure on one day may become important information at a later date.

Enter measurements in your tables. As you proceed with your project, make certain you include the units and the degree of uncertainty of each measurement based on the exactness of the measuring device. Record your error as a +/- to indicate the amount of uncertainty.

Make repeated measurements periodically. Some experiments (e.g., plant-growth projects) require repeated measurements over an extended period. Take measurements periodically (e.g., every day at 4:00 PM, every third day at noon) to reduce extraneous variables, and make entries into the log when you make the measurements.

Repeat the experiment, if necessary. After completing the experiment, you may decide you need to repeat the experiment for accuracy of your results. You may need to clarify or even alter the hypothesis, redesign the experiment, and get ready to begin again. You may learn more from the process of revision than you learn when all goes "perfectly." Remember, do not discard or remove any data from your scientific notebook/logbook. These pieces of data are often valuable later. Talk with your teacher or supervisor about improvements and, if necessary, begin the experiment again.

When other people make entries or comments in the scientific notebook/logbook. Material put in the scientific notebook/logbook by someone else must be acknowledged clearly, and that person's signature must be in clear view and dated.

Engineering/Computer Project Considerations

If you are doing an engineering project, after you have defined the need, developed design criteria, and done the literature search, you should:

- prepare preliminary designs
- build a prototype
- test the prototype
- retest and redesign as necessary

9.0 ANALYZE THE EXPERIMENTAL DATA

Organize your data. In order to look for any trends, your results should be organized in data tables. Computer spreadsheet programs such as Microsoft Excel™ and Vernier Graphical Analysis™ are useful because the program can graph your data from the spreadsheet.

Density of Sand Without Air		
Mass (g)	Volume (mL)	Density (g/mL)
26.38	10.0	2.64
26.23	10.0	2.62
26.18	10.0	2.62
134.90	50.0	2.70
132.88	50.0	2.66
51.54	20.0	2.58
73.84	30.0	2.46
31.52	12.0	2.63
32.00	14.0	2.29
32.24	13.0	2.48
23.77	9.1	2.61
13.25	5.0	2.65
15.09	6.0	2.52
14.26	6.0	2.38
15.67	6.0	2.61
	Average	2.56
	Standard deviation	0.12

Determine the precision of your data points.

9.1 ACCURACY VS. PRECISION, AND USING SIGNIFICANT FIGURES

In everyday speech, *accuracy* and *precision* are often used synonymously; however, these words do not mean the same thing to scientists.

Accuracy refers to how close the result of an experiment or a data point comes to the "true value." (See Percent Error below.)

Precision refers to how many digits your measuring instrument is able to determine in a measurement, or how many significant digits your instrument can measure. A good-quality measuring device can usually measure more precisely, that is, give more digits, than a poorer quality device.

Example: If you determine the acceleration due to gravity (g) to be 11.9971 m/s^2, your data is precise but not very accurate. (The number 11.9971 is precise to 6 digits. In other words, it has 6 significant digits.) A measurement of 10 m/s^2 is not very precise but it is quite accurate. (The true value for g is about 9.81 m/s^2.) Consult with your teacher or a textbook on how to correctly make calculations that take into account the number of significant digits in your data.

Precision is also used to discuss the variability of a set of data. This is discussed further under Measurements of Variability (see below).

Example: One student obtained the following data when measuring the acceleration due to gravity: 9.8 m/s^2, 9.7 m/s^2, 9.9 m/s^2, 9.6 m/s^2, and 9.8 m/s^2. Another student obtained this data: 10.5 m/s^2, 9.8 m/s^2, 8.3 m/s^2, 11.7 m/s^2, and 7.9 m/s^2. The first data set is very precise while the second is not. Both data sets give similar mean values and appear to be quite accurate.

Find the central tendency in your data.

9.2 MEASURES OF CENTRAL TENDENCY

The statistics listed below are used as a measurement of the central tendency in a data set. Most scientific calculators will calculate these statistics for you; learn how to use a scientific calculator.

- Mean or average
- Median - the middle data point
- Mode - the most common data point

Mean or average: $\bar{x} = \dfrac{\sum x_1 + x_2 + x_3 ... + x_n}{n}$ where x_n = each data point and n = number of data points

Determine the variability in your data. Variability refers to how close together your data points are or how close your data points are to given curve (often a line).

9.3 MEASURES OF VARIABILITY

- Range - the smallest data point subtracted from the largest data point
- Standard Deviation - (S or ς for samples, σ for populations)
- Correlation Coefficients (R) - used for data that has been curve fitted

Standard Deviation

Since most student science involves samples and not a whole population the following equation applies to samples:

$$\varsigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}}$$

where x_i = each data point and n = number of data points

Graph your data

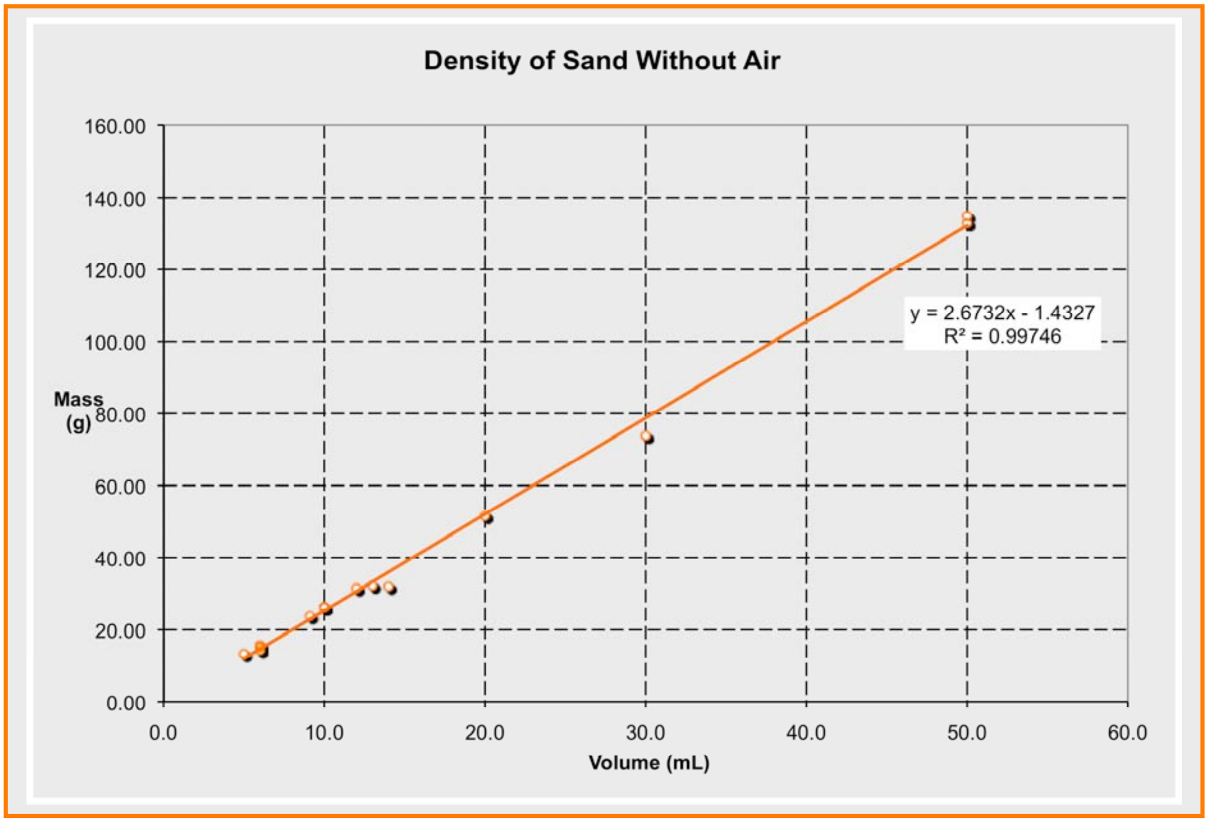
It is always a good idea to graph your data either on graph paper or using computer software such as Microsoft Excel™, Vernier Graphical Analysis™, KaleidaGraph™, or Mathcad™. The following are examples of common graph types:

- line graph
- bar graph
- pie graph
- pictogram
- histogram
- scatter plot

When both variables involve data that is continuous (decimal numbers can, in theory at least, be found) most scientists prefer to use scatter plots. You will be able to infer the “true” shape of the data with this type of graph. Scatter plots can be line- or curve-fitted.

Remember that each graph should have axes that are properly calibrated (i.e., each increment should represent the same numerical amount). Be sure to include the entire range of your data in the scales of your axes. The **independent variable** is plotted on the ***x*-axis**, and the **dependent variable** is plotted on the ***y*-axis**.

Does your data vary directly with *x* (that is, as *x* increases, *y* increases)?
Does your data vary inversely with *x* (that is, as *x* increases, *y* decreases)?



If your data looks as if it might be describing a line, you can do a best-fit line using a clear plastic ruler or using computer software. The correlation coefficient (R) is a measure of how closely your data is fitted (R=1 means that all data points are exactly on the line or curve). When using a ruler, make sure that you have as many data points above the line as below, and that the distances of the data points to the proposed line on average are minimized. Other kinds of curves can also be fitted using mathematics or computer software. By fitting your data to an appropriate line or curve, you can obtain an equation that describes your data. Predictions can be made from this equation, which can be used to verify your results with further experimentation.

Compare with accepted values to determine its accuracy.

9.4 MEASURES OF ACCURACY

Percent Error
If there is an accepted value associated with your data or if other scientists have data with which you can compare your data, the appropriate statistic for this comparison is percent

error. This statistic is used to assess the accuracy of your data.

$$\% \text{ Error} = \frac{|\text{your value} - \text{accepted value}|}{\text{accepted value}} \times 100$$

Hypothesis Tests

You may want to learn more about testing null hypotheses and how to determine confidence levels for the credibility of your results. The t-test is a hypothesis test used for small samples.

9.5 ANALYZING ERRORS

Ask yourself these questions:

- What were the limitations of your experiment?
- How were extraneous variables minimized?
- Comment on your percent error. Was this favorable or not favorable?
- What went wrong? What went right?
- How might you improve your experimental design in future studies?

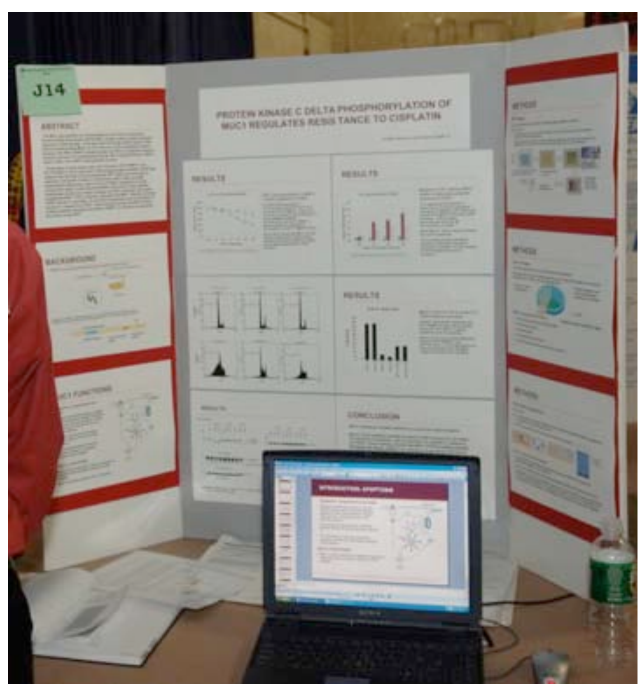
10.0 LOOKING FOR TRENDS AND FORMING A CONCLUSION

Now is the time to look at the results of your experiment and the analysis of your findings.

- Did you collect enough data?
- Do you need to collect more data?
- Were you variables and control properly designated?
- Which variables are important?
- How do your results compare with other studies? (Refer to your background information)
- Do your results seem reasonable?
- Are there any trends in your quantitative/qualitative data?
- What might explain these trends?
- How might the results of your work be relevant to society or to other scientists working in your field?
- Do you need to do more experimentation?
- Do your results support your hypothesis? If not, why not? Has your experiment tested your hypothesis?

Ask and answer as many questions about the project as you can. This will help to direct your thoughts and help you to decide whether or not you need to modify, do retrials, or complete the project at this time.

Remember one very important thing - keep an open mind about your findings. ***Never change or alter your results to coincide with what you think is accurate or with a suggested theory.*** Sometimes the greatest knowledge is discovered through so-called mistakes.



11.0 WRITING THE PAPER

Your report will provide interested readers with a comprehensive look at your topic and research. Your paper should include information collected during the research as well as a complete description of your experiment, data, and conclusion.

There are two types of science research papers, and they may be separate or combined. The first type is a literature review. In the literature review, you compile and summarize large amounts of scientific research done by others that cover the topic chosen for investigation. You do not include your own laboratory investigations in the literature review. The review should be extensive, citing as many sources as you can locate on the topic.

The second type of research paper describes the specific experimental project you have completed. It should contain an abbreviated (abstract) or full literature review as part of the background information as well as your hypothesis, experimental design (methods and materials), experimental results, brief data summary, discussion and analysis of the results, and bibliography.

You can do both types of paper separately, or put them together in one inclusive report. A thorough search of the scientific literature published on the topic covered in the project helps to make you an "expert" in your particular field of study, and prepares you to confidently discuss the area of study with others.

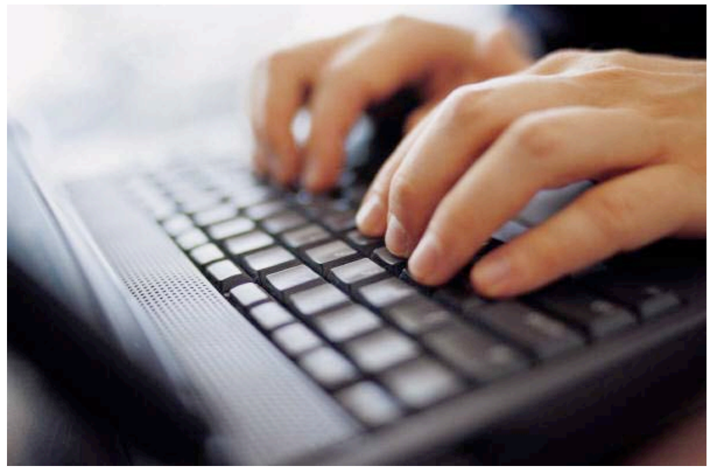
Use scientific terminology in the paper. It will help you to feel more at ease with the topic. Your job is to convey the facts and information you have gleaned in an organized, readable, and concise manner.

A good research paper should be written in the past tense and have the following components:

- Title and/or Title Page
- Abstract, Summary Page/Index
- Introduction, including Literature Review
- Hypothesis or Statement of Purpose
- Materials and Experimental Methods
- Data and/or Results
- Discussion and Analysis of Data or Results
- Conclusions
- Acknowledgements
- Bibliography

Considerations for Engineering or Computer Projects
- Title Page
- Abstract or Summary Page
- Introduction - Background from reading about similar devices or systems, how they work, their history etc.
- Statement of Purpose - What was the device, program or system designed to do?
- Materials and Experimental Methods
  - Describe the structure and parts. How does the device, system or program work?
  - Include a detailed schematic or algorithm.
  - Give measurable characteristics of the device or system (for example: dimensions, weight, power supply, voltage generated, software and hardware requirements).
- Data or Results - How did you prove your device or system works?
- Discussion and analysis

- If the system was tested over a range of conditions, graphs can be used effectively.
    - What problems prevent the device or system from being fully successful?
    - Give suggested improvements.
- Conclusion – Did the device or system do what it was designed to do?
- Acknowledgements
- Bibliography



After you have gathered all your information, you may find the following steps helpful:

1. Produce a report outline that provides a skeletal structure for the entire paper. A good outline will give direction, cohesiveness, and orderliness to the paper, and convey the information in a concise format. Be descriptive but brief. Reduce large quantities of information into brief "bullet statements" for use throughout the paper. Organize them into a step-by-step description to walk the reader through the project in an orderly progression. Use your sources to "work for you" and distill information into a reasonable length. When you write from the outline, each paragraph should have a topic sentence and a concluding sentence to direct the reader.
2. If you use note cards, organize these by sequencing them in a desired order.
3. Write an introductory paragraph that acquaints the reader with the research paper. Give a preview of information that is covered in the paper. Briefly highlight the main points of the paper (50 - 75 words).
4. Take material from the note cards and put it into written text.
5. Footnote or cite sources properly. Cite references directly within the paper with the citation set off by parentheses, and cross-referenced in the Bibliography or List of References. Use citations when you give facts such as numbers, data, and statistics, quote a source directly, cite another researcher's results, or cite information received from another expert in the field.
6. Integrate support material. Be certain that pictures, diagrams, tables, and graph axes are properly labeled and include units of measure.
7. Write a summary paragraph as your conclusion. Make a concluding statement and bring the paper to a close. It should state whether or not the results supported the hypothesis.
8. Be careful to acknowledge all borrowed material whether paraphrased or directly quoted.
9. Be careful to give proper credit. Use quotes and citations where appropriate.
10. Reference sources in the Bibliography, which may also be called the List of References, References Cited, Literature Cited, or Sources Cited.
11. Check spelling, grammar, and punctuation. Do not rely on software alone to do these checks.
12. Read the paper aloud and check for clarity and readability.
13. Have someone else read the paper.
14. Correct errors.
15. Use standard size (8½ x 11) white paper. Use standard margins. Type on one side only.
16. Have your report(s) with you as a part of your display when presenting your project.

Citing Sources; Avoiding Plagiarism in Scientific Work

When using the work of other scientists you must document their contributions by citing your sources of information. Scientists use the American Psychological Association (A.P.A.) Guidelines, which differ from those used in writing English, or History papers. There are no footnotes at the bottom of the page. The acknowledgement of a direct quotation or your use of some one else's original idea is done within the text of the paper itself. Use citations to cite a fact, quote directly from a source, or to cite information obtained personally from an expert. The citation is set off using a "signal phrase" or with parentheses and is cross-referenced in the Bibliography.

1. **Book or Article:** Author(s) last name(s), year of publication
   "Many more worms were found in the dark compost than the light compost" (Martin and Stephen, 2000).
   OR
   Martin and Stephen (2000) found that worms prefer dark colored compost.
   OR
   Worms prefer dark colored compost (Martin and Stephen, 2000).

2. **Encyclopedia or CD-ROM:** Author or if no author is listed article title, year, encyclopedia or CD-ROM
   (Worms, 2000, Encyclopedia Britannica)

3. **Letter or Conversation with an Expert:** Name of expert, state "personal comm." (for personal communication), date of the communication
   Martin (pers. comm., September 13, 1952) said that worms prefer dark colored compost.
   OR
   Over 50% more worms were found in the dark compost than the light compost (Stephen, pers. comm., September 13, 1952)

4. **Internet source:** Author, date, and state "Internet"
   (Martin and Stephen, 2000, Internet) **OR** (Compost and Worms, 1952, Internet)

For more details you may want to consult A Writer's Reference by Diana Hacker or Purdue University's APA Style Guide (http://owl.english.purdue.edu/).

Bibliography or References

Most scientists use the American Psychological Association (APA) system for citation and references; guidelines are as follows:

1. Give the last name of the author followed by initials. Include all of the authors' names in full (not et al as is found when citing in text).
2. Alphabetize your entries by last name of author or editor. If there is neither, use the first important word in the title.
3. With two or more works by the same author, use the author's name for all entries and arrange the entries by date, the earliest first.
4. Indent the second and additional lines of each entry five spaces.
5. Place the date of publication in parenthesis immediately after the last author's name.
6. Underline or italicize the titles and subtitles of books; capitalize only the first word of the title and subtitle (as well as all proper nouns).

7. Before page numbers of newspaper articles and works in anthologies use “p.” or the plural ‘pp.” before the page numbers. Do not use these before page numbers of articles appearing in magazines and scholarly journals.
8. The publisher’s name may be given in short form as long as it is easily identifiable.

Note the punctuation in the samples below. Each item is separated by a period “.” A comma “‘,” precedes the pages. A colon “:” separates city of publication and publisher.

BOOKS

Author’s last name, Initials. (Year of Publication). Title of Book. City of Publication: Publisher

Emery, K.O. (1997). <u>A Coastal Pond Studied by Oceanographic Methods</u>. Woods Hole, MA: Oyster Pond Environmental Trust Inc.

JOURNALS, SERIALS OR MAGAZINE ARTICLES

<u>If Author is Named</u>:

Author’s last name, Initials. (Year of Publication). Title of article. *Journal name (or abbreviation). Volume (number)*, page numbers.

Weiss, P. (May 13, 200). Gravity gets measured to a greater certainty. *Science News, Volume 157, No. 20*, 311-312

<u>If No Author is Named</u>:

Title of Article. (Year of Publication). Journal Name. Volume (number), page numbers.

Gravity gets measured to a greater certainty. (May 13, 2000). *Science News*, Volume 15, No. 20, 311-312

NEWSPAPER

Author’s last name, Initials. (Year of Publication, month, day). Title of article. *Name of Newspaper*, Page number(s)

Zuckoff, M. (2000, 10, 31). What’s killing the coral reefs? The Boston Globe, F1-F2

PERSONAL INTERVIEW, LETTER OR TELEPHONE CONVERSATION

Name. Title or position, Institution, Location. Type of communication, date(s) of interview(s)

Shore, S. Senior Scientist. Woods Hole Oceanographic Institution, Woods Hole, MA. Pers. Comm., June 14, 1984.

ELECTRONIC INFORMATION

Give the same publishing information that you would give for any material and in addition give the pertinent information about the electronic source (address). For material retrieved from an online source, also provide the date that you accessed information.

CD-ROM

Author, A. (Date). Title of article. In Title of the database (Type of medium). Available: Supplier/Database Identifier or Number (Version).

Lawrence, J. C. (1996). Algae. In The 1996 Grolier Multimedia Encyclopedia. (CD-ROM). Available: Mindscape, Inc. (Version 8.0.3)

INTERNET SOURCES

If Author is Named:

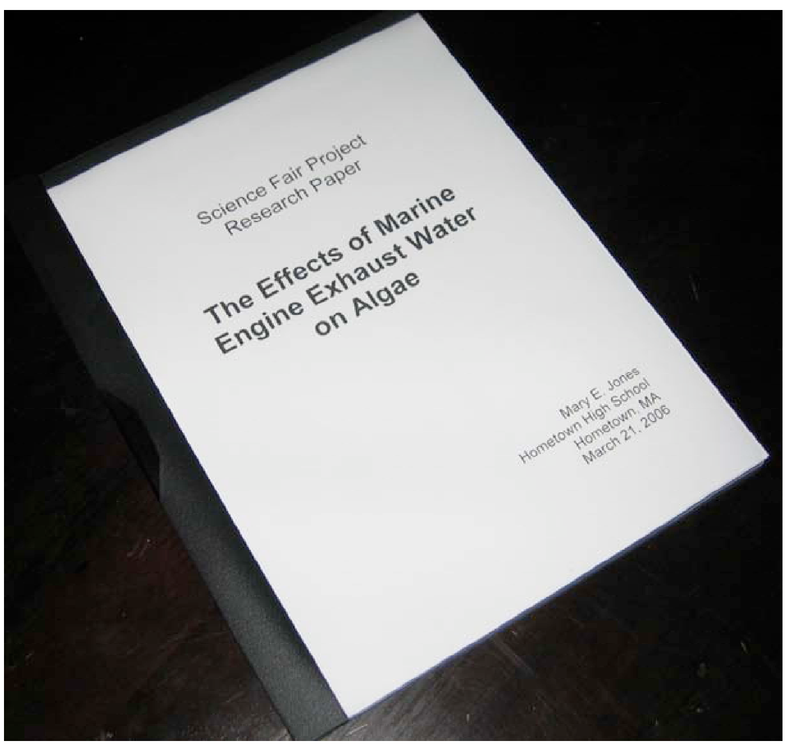
Author, A. (Date). Title. <address>

Smith, M. (Dec. 25, 2000). How to Do Your Science Project. <http://www.scifair.com/>

If No Author is Named:

Title. (Date). <Address>

How to Do Your Science Fair Project. (Dec.25, 2000). <http://www.scifair.com/>



12.0 WRITING THE ABSTRACT

The abstract is the last part of the project report to be written. It is written after the project is completed. It is a short summary of your project that informs the reader what the project covered, and what has been accomplished.

Often the abstract has to conform to a specified space or number of words. Making every word count is very important when you are completing an abstract.

Only minimal, if any, reference to previous research and experimental work may be included. The abstract focuses on this year's work. It should not include acknowledgments or the work done by a mentor.

An abstract should include:

- A statement of purpose or a hypothesis.
- The experimental design, descriptive outline of the procedures or methods.
- A summary of results.
- Your conclusion.
- Application of the research project, if you have space, and your ideas for future studies.

Four Paragraph Format

1. Brief Background and Statement of Purpose
2. Method or Design
3. Results
4. Conclusions and Applications

The conclusion should include a summary and analysis of the results and answer the reader's questions of how the results related to the purpose. It should state the relevance or significance of the results and state practical applications of the research to everyday situations.

Writing, editing, and rewriting to make every word count is a very important part of the abstract-writing process.

Sample Abstract

Effects of Marine Engine Exhaust Water on Algae
Mary E. Jones, Hometown High School, Hometown, MA

This project in its present form is the result of bioassay experimentation on the effects of two-cycle marine engine exhaust water on certain green algae. The initial idea was to determine the toxicity of outboard engine lubricant. Some success with lubricants eventually led to the formulation of "synthetic" exhaust water which, in turn, led to the use of actual two-cycle engine exhaust water as the test substance.

Toxicity was determined by means of the standard bottle or "batch" bioassay technique. Scenedesmus quadricauda and Ankistrodesmus sp. were used as the test organisms. Toxicity was measured in terms of a decrease in the maximum standing crop. The effective concentration - 50% (EC 50) for Scenedesmus quadricauda was found to be 3.75% exhaust water; for Ankistrodesmus sp. 3.1% exhaust water using the bottle technique.

Anomalies in growth curves raised the suspicion that evaporation was affecting the results; therefore, a flow-through system was improvised utilizing the characteristics of a device called a Biomonitor. Use of the Biomonitor lessened the influence of evaporation, and the EC 50 was found to be 1.4% exhaust water using Ankistrodesmus sp. as the test organism. Mixed populations of various algae gave an EC 50 of 1.28% exhaust water.

The contributions of this project are twofold. First, the toxicity of two-cycle marine engine exhaust was found to be considerably greater than reported in the literature (1.4% vs. 4.2%). Secondly, the benefits of a flow-through bioassay technique utilizing the Biomonitor was demonstrated.

13.0 PREPARING YOUR BOARD AND VISUAL DISPLAY

The visual display on the board is meant to attract attention and provide information. Your visual display should challenge onlookers to want to know more about your project. Photographs, graphics, and tables, along with the written text should be included. A well-thought-out and interesting title can also attract attention.

Only material from this year's project can be placed on your board. If your project is a continuing project, a short background statement (1 to 2 paragraphs) can summarize the preceding year's work as background only.

You should take pride in the assembly of the board and it should reflect your work as you want it represented. Neatness, completeness, and clarity are very important. The board and visual display should help you to present your project logically and serve as a prop for you to illustrate what you have done.

Read the rules that govern what can and cannot be exhibited before you begin. Pictures can often help you to show what you have used, and thus you do not need a lot of equipment or glassware and chemicals in your display.

Be creative. Use color combinations that are pleasing to the eye. Arrange the board in several ways before attaching all of your materials. Keep background spaces to a minimum. However, do not crowd tightly so that everything seems too packed. Keep it simple. Make it easy for the judges and others to assess what you have done.

The following items are part of the board:

- Title - an attention grabber to make someone want to know more about the project
- Introduction or Background
- Problem or Purpose
- Hypothesis
- Procedure or Experimental Design
- Materials Used
- Results (Data, charts, diagrams, graphs, photographs of the results, etc.)
- Analysis
- Conclusions
- Bibliography (Optional; your bibliography may be placed in the notebook instead)
- Applications
- Future Applications or Future Research

Carefully check the safety and size before you cut your board to size. Poster board - which may need to be reinforced so it can stand alone - mat board, and foam core boards are easy to work with and are lightweight.

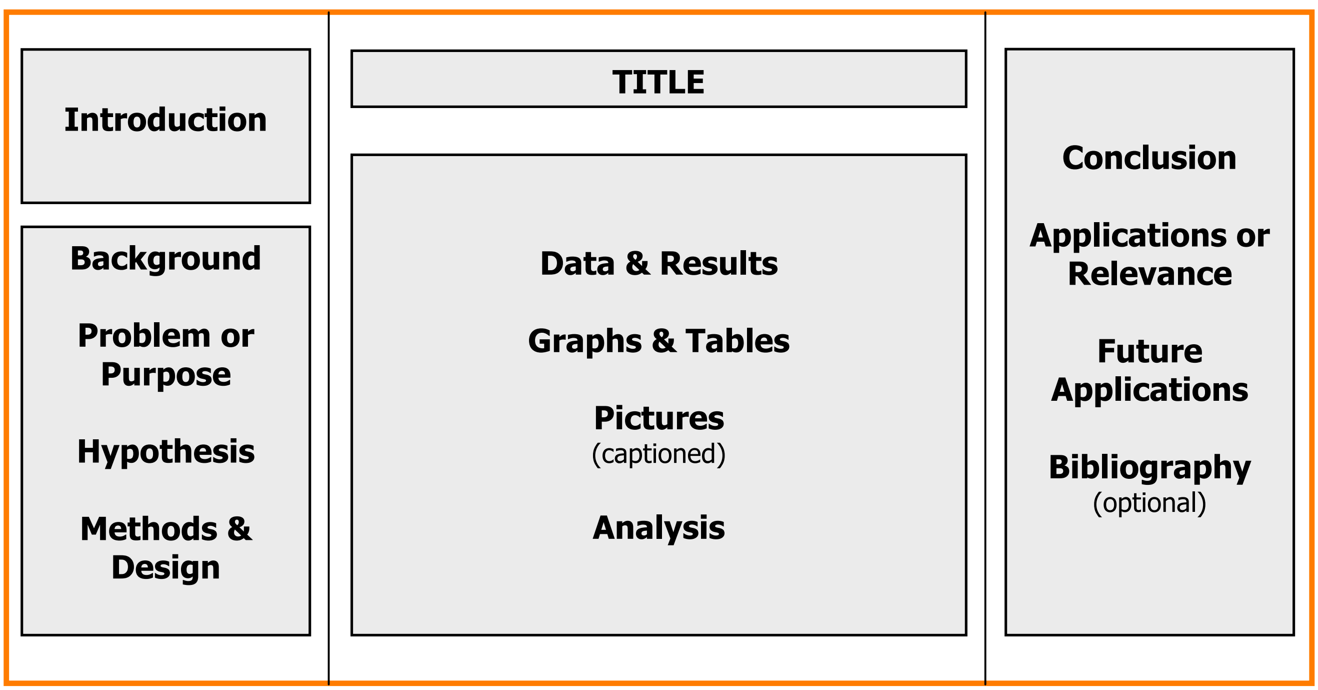
Your project title and section headings on your board should be large enough to be easily read from six feet away. The regular text displayed on your board should be readable from a distance of three feet. Although you may be tempted to make your board larger, remember that your board should not be mostly empty space. A smaller size board that is nicely laid out and tells the story is far more attractive than a large on that is not filled.

Correctly and clearly label graphs, diagrams, and tables. Make certain that the graphs are titled and have both axes labeled clearly and accurately. Use photographs to validate and help explain parts of the project that would be difficult to explain, or that would require time to explain. You must obtain informed consents from any people you show in the photographs. Decide if photographs of this type would be better placed in your notebook or a photo album rather than on your board. Also, you must have permission to use pictures from books or other sources.

Acknowledgments should be placed in your log, not on the board.

Remember, an eye-catching display helps to showcase your project, but your personal presentation is far more important. The board does not need to be expensive. Equipment built by you, construction paper, markers, and poster board can be very effective and inexpensive.

SAMPLE BOARD



14.0 ORAL PRESENTATION

Be ready to explain your project to another person — possibly a student, a parent, a teacher, or a judge. A description of each part of the project — from how the idea originated, through the literature search, the formation of the question or problem, the hypothesis, experimental design, results, analysis, conclusions, and future applications — is important to relay to the listener.

Below are some key points to a good presentation.

- Be positive and confident of your work. You have worked hard and know your project better than anyone else. Now present!
- Practicing ahead of time in front of a mirror, family members, friends, your class, or others is very important. Sometimes practicing in front of a video camera can be helpful. While watching the video you may notice habits or ways of presenting that you wish to change.
- Try not to read from a script.
- Look interested in what you are doing. The judges or other interested people want to know what you have done and what you have learned.
- Leave gum, CD Players/MP3 Players, Cell Phones, Laptops, and other distracting materials at home during the fair.
- Dress appropriately and neatly. Wear comfortable shoes. Remember, you are representing yourself, your family, and your school at all times.
- Keep eye contact with your listeners during your presentation.
- Use your board/poster as a prop and tool to help you present you work.
- Present your work enthusiastically. Make certain you guide the listener or judge through your project. Have notebooks and reports in clear view and refer to them in your presentation so that the listener or judge will be cognizant of the amount of time, work, and effort you have invested in your project.
- Learn the judge's name (ask for it if he or she does not have a nametag), and address the judge using his or her name. Learn from judges by asking them questions, or asking if they have additional information or suggestions that you might consider. Be sure to record any suggestions that they give you.
- Answer all questions that you can. If you are not certain of an answer, you might say, "I'm not certain, but I think it might be..." If you do not know the answer, you might give the person an idea of how you would find an answer to the question. It is also appropriate to say something like, "That was not part of my research or experimental plan." You might ask the person if he or she knows and could help you. Use your judges as resources. Sometimes members of the public audience can give helpful suggestions. Note any helpful information in your logbook.

- Incorporate new materials from suggestions into your presentation. Practice again before moving on to another level of competition.

You may find the process difficult when you start, but every step forward makes the job easier. Many students find this part of the process extremely beneficial for other public speaking situations, job interviews, and college interviews.