THE ULTIMATE SCIENCE PROJECT NOTEBOOK

Castle Heights Press, Inc.

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Introduction

Most science project books are filled with the classic projects you have seen many times in science fairs. These projects teach a little about the scientific method and a lot about cookbook science. Most of the projects are well known and seem to take a lot of the parents' time to help the student put together and display a science project. For these reasons I have put together this booklet containing some suggestions to make your project both fun and real science.

There is a discussion of the scientific method and a short instruction on the creation of charts for your paper. After that, forty-five good projects are listed with information on getting them started. I do not claim that the projects are easy, but they are definitely good science.

Most of the time spent on a science project is actually wasted time. The student spends a great deal of 'thinking' about what to do for his/her project, not actually working on it. With a few pointers, a student should be able to follow through with a project. The actual working out of the project is not such an ordeal, especially if the student is interested in the topic.

The hardest two things about a science project are the decision of what topic and the organizing of it. In these two areas, the student can and should have help.

The Scientific Method

An Abbreviated Scientific Method

These are the steps you might use for your science fair display.

Statement of the problem
Research of the literature on the topic
Hypothesis
Materials list
Procedure used
Observations
Calculations
Results
Statistical analysis
Sources of error
Conclusions
Possibilities for future research

As a high-school student, a good project is one which includes at least some attempt at all of these. This author has seen original research get overlooked in science fairs because the student's use of the scientific method was not clear.

Because of the nature of the judging, the scientific method has become an idealized concept, an end in itself. A project can be original, complete, and very nicely done but still not do well at a science fair, if the student does not know and use this set of steps. In addition, the student must be very clear about her/his use of them.

Some states require additional steps, like a list of acknowledgments. Do not forget them if you wish to do well in the contest. Also, do not leave steps out just because they are not listed in the science fair handbook.

The oral part of the science fair is usually designed to discover if the student knows her/his experiment and if he/she knows and has used the scientific method. I suggest that you make a point of using the steps in your oral presentation, as well as the words "control" and "experimental setup". You may have done everything quite well, but If a scientist is going to do serious and hopefully original research in science, she/he would use some variation of the scientific method. Obviously, a research report will not include all of these every time, so this is a generalized set of steps. But these are the steps usually used by students with winning science fair projects. For a wonderful and lengthy description of the SM-14, the scientific method in 14 steps by Norman Edmund, go to his website: www.scientific-method.com

This long list is not some form of advanced torture designed for scientists. On the contrary, once a scientist has an interesting question, these steps are all very intriguing, especially if she/he has stumbled onto something no one has done before. A scientist would probably only use a list of this type so that she/he would not forget some vital step before publication. Half-done research is no research at all.

As a high-school student, a good project is one which includes at least some attempt at all of these. This author has seen original research get overlooked in science fairs because the student's use of the scientific method was not clear.

I have included this commentary so that the student may not be overwhelmed at a science fair. If you are aware of these things beforehand, you can systematically accomplish the steps required for a good score and at the same time learn about how good science is done. The following is a list of the commonly used steps in the scientific method which you will want to include in your project.

Problem

The problem step is only a statement, a simple sentence or two describing the question you tried to answer. Just writing down the problem clearly is sometimes a real ordeal because it actually sums up what you need to do, but this step is critical. When you are able to write down exactly what the problem is, you will be able to clearly see the problem and this is very important to being able to solve it. Even though this step may be difficult, it is very important because it forces the student to organise his/her thoughts. This organization will be good for the rest of the project.

Research

The research step is very important. It prepares you to do the experiment. By consulting experts, you learn more about your topic in a very painless way. Interviews are very nice ways of getting information. The telephone can be the means to really update your research step. Beware of spending too much time on the internet as it can eat into your time in very unprofitable ways. As well, in many areas of information, the internet is less than accurate. Be sure to use credible sites for references and certainly record all of the bibliographic information for your paper. Check out the SM-14 for more ideas about how to go about this all-important step.

Hypothesis

After you have learned something about your topic, you should be able to take a guess about the outcome of the experiment. This guess is your hypothesis.

Materials and Procedure

Next, you will need a list of materials and a procedure. Many times one will follow the other as you concoct some type of setup you need for the experiment. Remember that it is normal for a student to have to change part of the experimental setup halfway through the process. For example, if a piece of equipment is too expensive, you can build one- no problem. If you don't have a balance scale, set up one using fishing string and weights. This very accurate type of scale still works as it did in ancient days, so don't be afraid use older methods.

Observations

The next step, observations, is easy to understand. The hard part is recording everything. I'll say that again, Record everything. The best way to do this is to use a spiral notebook as a journal with frequent entries.

Calculation, Results

The next four steps usually go together for the high school science fair or paper. You have the calculations you must make, and the answers you get from the calculations. These steps are the calculation step and the results step. If you do not have any calculations to make then you will not have these steps, but, beware, the projects which win are those which use numbers and calculations. For the calculation step, you need only display one sample of each type of calculation you use. The results of all calculations must be recorded and displayed.

Statistical Analysis

The statistical analysis step is the step which allows you to discover whether your results mean anything or not. You do this step when you have made calculations or have numerical findings. For example, you may have a large percentage error. This can mean a problem in the experimental setup, or it may indicate that you dropped something (a chemical or microscope slide, for example) and used the data anyway (a bad thing to do). If the percentage error in your experiment is around 25%, you might consider evaluating the sources of error since this is a very large number. A better number might be 15% or less in a high school project (of course, this actually will depend upon your project)

If the difference in two findings is not statistically different then you must consider them as very nearly the same number. For example, you have ten numbers: 2, 4, 7, 4, 1, 4, 4, 8, 9, 9.2. The 9 and 9.2 are within the same order of magnitude when compared to the other numbers, and so you may be able to round the 9.2 to 9. Of course in this case, I would have to ask why your readings do not have the same number of significant digits.

Sources of Error

Everyone who has done a science project needs a sources of error step. This is because every experiment has some error. In order to make your experiment as complete as possible, you should think about these errors which crop up. During the experiment, you must try to reduce the effects of the errors, and after the experiment you must list the ones which still remain. It may be that you live in an area which does not require this step, but no really good experiment would be complete without it.

Conclusion

The conclusion must have the researcher's thoughts as to why it happened, what exactly happened, and possible ramifications of the experiment. This is the time for the investigator to expound on the subject of the experiment. In a good conclusion, the researcher will compare his/her research to that which has been done before. Many students have skimped on this step because it is last and they need to be done, but this is the one step which you will not wish to skimp on. This is the step the judge will most likely read first! Write the answers to these questions:

- What happened?
- Why did it happen?
- What factors influenced the results?
- Did the errors affect the results?
- Would you have changed the experiment in any way and why?
- What is your conclusion about the experiment: did it show what you meant for it to show?
- How did your experiment compare with that of others (the research step?)
- Did your results agree or disagree with the previous researchers' work?

- Does the result you got affect anything else in our lives?
- Should it change how we do something?
- Will you follow up with another experiment?
- What will you change or investigate next?

I have noticed that students sometimes have a problem distinguishing between results and conclusions. The result of the experiment shows literally what happened and the answers to very specific calculations while the conclusion answers a great many more questions. (See above)

For the best results, use the scientific method in your research and project. Remember that we do these steps to make our work more meaningful and accurate. The Scientific Method has been called the greatest idea of all time and although it may not be the greatest idea, it is surely a great idea which has had tremendous impact on our world.

Chart-Making

The purpose of any chart is to display data in such a way that relationships between pieces of data can be more easily seen. For example, a list of temperatures does not show a clear boiling point, whereas a plateau in the rising temperature will be perfectly obvious on a graph of the same data.

With this idea in mind, the type of chart used will affect the clarity of the data. You can use tables, graphs, pie graphs, or bar graphs but the line graph is usual in a scientific paper. The following rules will help the student prepare a professional-looking line graph.

1. The paper should frame the chart so that the chart takes up most of the paper.

2. The junction of the x-axis and the y-axis should be at the bottom left hand corner (within the margin, of course).

3. The points along each axis should be evenly spaced and should be on the lines of the paper, not in the spaces.

4. The points marked on the axes should begin their numbers just below the data collected and end just above. Example: If the first point was collected at 15^{o} and the last at 87^{o}, the axis should be marked off from 10^{o} to 100^{o} in steps of 5^{o}.

5. Care should be taken to make accurate, small points for your data. Use a very sharp pencil to give an accurate point.

6. The title should be in capital letters, printed.

7. The lines should be drawn in gentle curves which leave few data points far outside the curve.

8. Each line should be plainly labeled, either by coding or

with neatly printed words and an arrow. If coding is used, for example using color, a legend explaining the code system must be included to one side.

9. Both axes must be labeled, for example:

TEMPERATURE—>

10. A note on computer-generated charts: Ensure that as you input your data to produce the chart that you have a solid understanding of what it is you are trying to plot. Spreadsheet programs have excellent chart-making capabilities, but you need to know which data goes on what axis. Sometimes it is helpful to sketch what you think the chart will look like so you can uncover errors if you have plotted the computer data incorrectly.

Remember, a good chart, whether hand-drawn or computer-generated, includes the following: your name, the date, a title, labeled axes, labeled curves, and numbers on the axes to identify quantities.

Picking Your Topic

For most students deciding on a topic is the hardest part of doing a science fair project. So, the sooner you make this decision, the quicker your project will be finished.

1. What is an interesting field of science for you? The way to answer this question is to consider your own interests first, then look at the topics you see on the science fair guide. Does your topic fit in there somewhere? If so, then you are OK and you should go on to the next question. If not, then you may need to consider asking for some advice on fitting it in. Nearly all interesting subjects can be used in a project; it may take some creativity to do so, though. For example, it you are interested in mechanics, there is no topic listed, but there are lots of ways you could use that interest. For example, you could compare the thermal buildups in an engine while using gasohol compared to gasolene. Does it run hot? Do additives in stored gas containers sink to the bottom of the tank? These could be used under the heading of 'engineering' or 'physics'. Just do what you are interested in and get help to put it in the appropriate heading.

2. What part of the field you named coincides with your hobbies? Do you race radio-controlled cars? Have you planted a garden from seed?

3. Now, think of a modern question or problem which touches the subject. For example: “Could a form of pollution affect my seeds? If so, what is it and how might it hurt them? (or help?)” Or, “Can I shield my radio-controlled car from strong radio frequency (RF) signals which take over my control occasionally?”

This type of questioning will give you a problem topic. This problem will not be just any problem but one which applies to your own interests. Many students think of a good topic but never really get to a problem. In an experiment, you must try to answer a question or solve a problem.

4. How could the problem be tested for an answer? Once you have a problem, you need to think of a way to test it.

5. How can I measure something which would answer the question and allow me numbers that I can chart for an answer? This is important to your project. You really need a problem which will yield numbers or something you can chart. While this is not always true of science in general, it certainly is for a science fair project.

6. How can I do this project with what I have already or can easily get? This is the killer for some projects. Those students who do well at national meets oftentimes have access to some pretty cosmic equipment. The normal person must overcome this by ingenuity. If you can figure out how an instrument works you can build something to substitute. For example, an ordinary read head for a tape deck can be rigged to read the magnetic signal from a rock. If you don't know how, you can certainly ask questions. Sometimes, the people at Radio Shack or the local ham radio club can give you a lot of help with that sort of problem.

For project minded people: If you find yourself spending excessive time building a tool for your project, remember to ask yourself if you can do without it. The building of the instrument, while a worthy project, is not a problem in itself for a science fair. You need to keep focused on the problem you are trying to work: the question you are trying to answer.

7. How can I narrow my topic question to ask only a very specific question? A nice, narrow topic question will yield nice, narrow results. Next year, you can carry on the research and answer other questions which relate to this year's question.

Now you should have a topic you are interested in and have questions about. It is a topic question which can be measured and will result in numbers. It is a modern question, having to do with modern problems. It is a question you can answer using equipment you have.

Action Plan

Steps for deciding on a science project topic:

I. Decide on an interesting field.

II. Choose a subtopic which relates to your hobby.

III. Choose a modern problem which relates to the subtopic.

The following are important to this choice:
1. Topic problem must be able to be tested.
2. Topic problem must be quantifiable, i.e. yield numbers
3. Topic is within the means of student, that is, the student must have the:
a. Research sources available.
b. Equipment available.
c. Time to do the project.

IV. Write out your question. Begin your logbook.

V. Research the question and the related topics. Use the following resources:
A. Use the library (concentrate on periodicals).
B. Interview an expert.

VI. Write out your hypothesis.

VII. Determine your procedure. Go ahead and do these steps:
A. Set up your equipment.
B. Write out the procedure.

VIII. Perform the experiment. This includes:
A. Standardize the equipment. (Calibrate the instruments, etc.)
B. Do the experiment.
C. Write out your observations and sources of error.

IX. Evaluate the results by doing the following:

A. Compare your results with your problem as written. Did the experiment answer your question?

B. Write out your results and calculations steps.

X. Conclusion.

A. Compare your results to your hypothesis.

B. Write your conclusion.

XI. Put together your paper.

A. Finish all steps.

B. Put the written work in order.

C. Have someone proofread your paper.

D. Write your abstract.

XII. Finish your logbook.

XIII. Put together your display.

XIV. Prepare your oral presentation.

Electromagnetic Radiation

1. Determine optimum shielding against radio frequency (RF) radiation. Place a radio under a box while it is on and receiving a signal. Wrap different types of materials around the box in an attempt to keep the radio signal from reaching the radio. When the RF is blocked, the radio will receive nothing. When the signal is interfered with, the radio will emit static. Be sure to try metallic forms of shielding like foil, wire crisscrossed over the box, chicken wire, or window screening. Some of these will protect sensitive devices in your home from outside interference from radio frequency sources. Also, it appears that humans need protection from such sources of radiation. There is evidence that brain cancer can be induced by sleeping near radiating power lines. Basically, anything using electromagnetic pulses is sending out some form of radiation, possibly radio frequencies. *Note: radiation here refers to that which is usually termed electromagnetic radiation, not nuclear radiation. Light is one form. Radio waves are another.*

Devices in your home which produce RF are usually shielded to protect you and other appliances. Computers, microwave ovens, etc. are shielded. When RF escapes from an appliance, the appliance is said to be "leaking" RF. Shielding on appliances is usually connected to the ground wire of the plug. This connection allows the RF energy to "drain" away. It would be a good idea to connect your shielding to a ground like a radiator, metal waterpipe, or metal rod driven into the ground.

2. The previous idea can be done with light also by using much finer shielding, like polarizing filters. The transmission can be merely a light beam, or you can modulate the light

beam with a radio signal using infrared sources and recievers. Microwave ovens are shielded in much the same way.

3. Determine the optimum position to watch TV without receiving RF (radio frequency) radiation. Electromagnetic waves radiate in a pattern which can be calculated by using the Inverse Square Law (ISL). While watching a leaking TV, a person may be receiving radiation. The amount can be calculated by using the ISL and then can be verified by using a meter to measure the actual leakage. The calculations would give you the hypothesis, and actual data would give you results.

4. You could use a meter to determine the devices in your environment which radiate the most RF. Then you could devise shielding which would block out this RF radiation. You would hypothesize which devices are creating the most radiation and/or what would shield them most effectively. Remember that the device must be on in order to radiate. If you had another device which would measure other forms of electromagnetic radiation than radio waves, then you can measure that form of radiation. You must be clear on what frequency of electromagnetic radiation you are measuring.

5. Design an energy 'clean' house. Research has been published on the hazard of radiation of appliances, devices, and wiring within the house. Cancer has been linked to nearby power lines and the use of heating blankets. You may enjoy the challenge of designing a house so that the wiring in the house is restricted to a certain few walls. One of the challenges of this project is the fact that an architectural convention is that you should have multiple outlets in every wall and even on the floor. In order to overcome this type of strong conventional idea, you must design a pleasant, easy living house arrange-

ment, at the same time minimize the wiring in the walls. Try to think of original ways to configure rooms in order to accomplish your objective. When you are done with your design, consider making a model of it out of balsa wood with no roof, no siding, no covering over the walls. The wiring can be represented by monofilament fishing line or colored sewing threads. An additional plus for this type of house is the decrease in the interference on TV sets and computers caused by 60 - cycle hum from the current flowing through the wires in the walls.

6. Would your design reduce the radio frequency radiation in the house? How would you test this? Remember that the wiring which carries a current will deflect a compass. Could this property be used to detect electromagnetic radiation? If so, which frequencies would it detect? These are good questions for the beginning of a project. Remember, this property is one which could be use to perform other experiments than this one.

7. Another good experiment is to determine which frequencies of the electromagnetic spectrum a compass will respond to. Light? Microwaves? A homemade compass Scouts have made for generations has little metal in it. To make one you take a magnetized needle and balance it on a cork which is floating in a bowl of water. It will respond to the Earth's magnetic field. Does it deflect when placed within a working microwave? How about when placed near a working microwave?

8. There are standing waves in a microwave. These waves create patterns of interference within the microwave. These interference patterns are the cause of irregular cooking in the device. By testing the dryness of damp paper after it has been cooked in the microwave, you would be able to see evidence of irregular cooking. It will only be evident if you have removed the rotating glass within your microwave so your microwaved object does not spin. If you use construction paper you should be able to easily see the still wet areas and the almost burnt areas. Tape the construction papers at regular layers within the microwave. (For example, one inch between layers.) They should form horizontal layers of colored paper. Zap the papers

for the designated time and then remove the papers. Be sure to number them in order. Use the data to make an energy map of the waves in the microwave.

Test your results by over-cooking a large flour tortilla. The brown areas should show the places where the microwaves constructively interfere with each other. You may be able to point out areas of destructive interference. Be sure to make a drawing of your tortilla recording the areas which were burned.

In addition, you can use a thin layer of brownie mix to correlate the standing waves with the cooking temperatures of the food. Remove from the microwave oven when parts of the dough are bubbling. Record the temperature of specific areas in the brownie mix. Use a thermometer which quickly registers changes in temperature. A laboratory thermometer is good for this experiment. Draw your brownie cake showing the areas of different temperatures.

9. Water transmission of light. In order for animals to live in water, either in lakes or in the seas, plants must be able to produce carbohydrates by means of light. The depth to which light can penetrate water is a limiting factor to the production of photosynthesis. Many things can affect the passage of light: pollutants (in and on the water), silt suspended in the water, even the volume of plants in the water. Any of these factors can be measured for a science fair project. Your control will be a volume of clean water without obstructions. Your light meter should be calibrated, either by using a photometer (from a camera) or by marking your homemade light meter at discrete intervals. This way you will have numbers which can be used to make charts.

10. Another way your light meter can be used is to measure the transmission of a specific frequency through the water.

For example, an ultraviolet (UV) light source will also pass through the water, but in this case, it will do damage to whatever organisms are down there. In another example, blue light will pass through water to a different depth than red light.

11. The reflectivity of water will change according to those things resting upon it. Since so much of the Earth's surface is covered by water, if there were widespread pollutants in the water, the total reflectivity of the Earth could be changed. You could measure this using your light meter by bouncing light off of a container of water. Then, you would vary the pollutant and re-measure the reflectivity. There is a lot of research available on the total energy reflected back into space from the surface of the Earth, mostly from the surface of the oceans. A change in the reflectivity of the surface of the oceans could change the thermal environment of the Earth resulting in a cooler or a warmer Earth.

12. Measure pollution: Your light meter can measure dif-

ferences caused by such pollutants as cigarette smoke and the smoke from burning leaves.

The damage that these types of airborne pollutants can cause on plants, buildings, etc. is well documented. You can measure the amount of these things in your own environment. The burning of coal and wood results in pollution which will hang heavy and measurable in the air. Good, clean air can be measured on a cold, clear day after a cold front has passed through. This would serve as your control.

13. Your light meter can test the reflectivity of light off of plant leaves. On the inside of a plant, light can be reflected off of other leaves to provide a means of photosynthesis to the leaves within the plant. The impact of this would be to increase the productivity of plants, especially in areas where sunlight is limited such as underneath the canopy of other plants.

14. The penetration of various light wavelengths through media such as pollution, clouds, sea water, etc. is a useful bit of information.

You would use a light source, possibly infared or ultraviolet, or any other color for that matter, and attempt to transmit it through the medium. You will need a receiver for the correct wavelength. The receiver will need to be calibrated to some standard. You could make your own standard by marking your meter.

This experimental data could be useful in measuring pollution or measuring thickness of fog as for runway instrumentation.

Plant Growth and Light Color

15. The color sensitivity of the photosynthetic cells of a plant is fairly well documented, but the experiment can be done in a manner which would make it a good project.

The key ideas in this case are to set up a well-designed experiment and to get results which are numerical and can be graphed. Your experiment should have a good control (in this case, natural light) and you should vary only the factors you are measuring. This is true for any experiment, of course, but when using a classic project, you must be especially careful to have clear controls and variables. A good way to vary this project is to use sprouts and test their germination with various light sources. Since seeds usually sprout easily and quickly, this variation will work for weekend projects. Seeds you can use are popcorn, beans of all types, celery seed, anise, or dill.

16. Another idea is to use potatoes. You know that they will turn green and sprout in the presence of light. Will they turn green in all frequencies (colors) of light? Is there a certain color of bag which would prevent the potato from turning green before it is eaten, or while it is still in the store? The green potatoes have a bitter taste and contain small amounts of solanine which is a poison.

Temperature Effects on Electronic Equipment

17. Measure the voltage of a battery at different temperatures, stability, type of battery. This could be useful information for campouts or survival situations. The output should be measured in volts with a voltmeter. Use standard batteries, not nickel-cadmium batteries. Remember you are not directly testing the products, i.e. which is the better battery, but the response of battery (i.e.) to low temperatures. You may discover that one particular battery is better at low temperatures, but that knowledge is incidental to the experiment. Your experiment should not be a consumer report type of project.

18. Test the temperature response of a load in series or parallel. The load could be a string of Christmas lights. If the temperature outside is below freezing, your lights might need to be either series or parallel strings. One of the two may respond better to temperature changes. You can determine if this is true.

19. Use the computer space bar to measure reflexes vs various factors, like fatigue, hunger, high blood sugar (after a Snickers Bar), with competing noises, and/or people.

You will need many test runs (approximately 10) in order to verify your data. Write your own program for this: a go statement, and a stop statement with a counter loop. Your program could ask people questions which would put them into certain classifications, like 'How long since your last meal?', and then put the user into the group closest to the hour, i.e. 2 hours. Your previous data analysis could allow your program to give the user some rating, like fast, average, slow. A more advanced program would take the new user's data and calculate it into the original data to build up the data base. Your charts would be good since you can get lots of data for this experiment.

20. In swim meets, the swimmers are told to rely upon their ears to know when to dive in. They are supposed to respond when they hear the gun go off, not when they see the smoke. This is supposedly because the brain can interpret auditory signals faster than it can interpret visual signals.

You can check this idea out by devising a signal which will change so that you must be able to recognize the change. Synchronize an auditory signal like a metronome and a visual signal like a flashing light. As you increase the speed of the beeps and the flashes, you will get to a point where your ear will not be able to recognize different beeps, but will hear only a constant tone. Likewise, as you increase the frequency of the flashing light, soon you will get to a point of being unable to distinguish the flashes but will instead see a constant beam of light. Does this event occur at the same frequency? Does this frequency difference hold true for other people? You may not have a number for these frequencies. Since the light and sound waves are synchronized, there is no problem with not having a number to which to refer. If you can quantify these frequencies, your project will be more complete, but it is not necessary for a significant finding.

Can you think of reasons which could explain your responses (or those of your subjects)? Were you slow or fast in response to the sound? How did you respond to the visual imput? Were you faster or slower on visual in comparison to sound? Be sure and put these answers in your conclusion. The concept of the speed of auditory and visual discrimination has significance in areas of human life which depend on the speedy recognition of a signal, for example, the warning lights in the cockpit of an airplane.

School Supplies

21. Test the tensile and/or shear strength of different brands of glue. Get four brands of white glue. Put dots of glue on popsicle sticks and glue them together. You can measure the weight it takes to separate them. This way you can measure the tensile strength and/or shear strength. The variables which will affect this experiment will be at least the porosity of materials used (the popsicle sticks used), the type of glue, the humidity of the air of the environment they dried in, the drying temperature and, of course, the different amount of weight with which you tested it.

22. Does epoxy work when mixed in non-fifty-fifty combination? Your younger brother stomped on one of your epoxy tubes and you can only save a portion of it. What will be the effect upon the epoxy after you have mixed it? Will a 25-75 mixture work just as well? If there are differences, what are they and how will they effect the bond?

23. You can test which eraser works best. You would build a machine that equalized the pressure/footprint of the erasers and try to erase a standard width pencil line under equal conditions. You would want to eliminate all of the variables, except the one you are measuring, in this case, the type of eraser. The pressure on the eraser in use can be standardized by a device which would place the same weight upon the eraser while it is erasing. The differences in the lines erased can be eliminated in much the same way, by using a standard number 2 pencil, for example, and applying the same weight to the pencil as it is writing. Temperature can be held constant, or you might vary it, too. Some erasers might work better when frozen.

Water Flow Rate

24. Make a comparative flow analysis of various drinking straws by attaching a plastic hose to the straw which would connect it to a source of water. The source of water should be above the tube and the straw so that the water will siphon down into another container. Measure the amount of time it takes for a specific amount of water to flow into the bottom container. Make the straw the constricting point in the sequence so that it is the part which limits the flow of water. Make the water volume large enough to get a reasonable time (not seconds, but minutes, if possible). Check the straws for flaws before you test them. You might try other fluids like milk shakes, ice cream slurries, etc.

Temperature Effects on Tone

25. Test the tone of a stretched wire and observe the changes which temperature makes upon it. Stretch monofilament line and tune it to a note. Then change the temperature and check for a new note. You could use an oven on warm and just move the line in towards the open door of the oven to increase the temperature. Check the note with some fixed key musical instrument, like a piano which has been tuned. Attempt to measure the change of tone, record, and chart your results. You could use a candy thermometer to measure temperature.

26. The previous experiment can be done using a metal rod, with certain modifications. You can start with a length of rod (You get these at the hobby shop in brass, copper, aluminum, etc.). Secure one end and tap the rod to produce a ringing tone. Determine the tone by comparing it to the tone of the piano or an electric tuner. Increase the temperature of the rod and tap it again matching its tone with the fixed tone instrument. You should be able to get a set of charts, one for each material and temperature range. Remember, the independent variable goes on the x-axis and the dependent variable on the y-axis. The independent variable is the temperature while the dependent is the tone. If you can explain the tone in terms of vibratory frequencies, you will have a better project.

Perception of Color

27. Record the colors 'seen' by the human eye after being subjected to a light (not the sun).

There is a progression of colors that you will 'see' if you stare at a light bulb and then close your eyes. This progression is supposedly the same for everyone. And it is not just colors, but patterns, too. Check this out for you and a few family members, then move on to friends. Record their oral descriptions of what they see (Use a tape recorder), and then make diagrams. Do not let any of your subjects see your diagrams, It will be talked about and you will influence the results of the experiment. You can number the diagrams in order to maintain some secrecy. The patterns humans 'see' is caused by the filament within the bulb, since it is so much brighter the the rest of the bulb. Maintain the same type of bulb and use a low wattage to protect the eyes. You will have to sign a statement of safety because you have used human subjects (or, rather, vertebrate subjects). You could make up a form for the people to fill out describing their 'sights'. Will everyone see the same sights, or does some factor like color-blindness affect it?

Blood Sugar Effects on Muscle Fatigue

28. Duration and strength of muscle action is directly related to blood sugar. You can measure muscle action and you can test blood sugar. If you cannot test blood sugar (that is, if you do not have access to a lab), then measure the amount of calories taken in during the test. Measure the muscle action by recording the number of times the subject can lift a weight, say three pounds, to shoulder height from resting upon the table. (bicep action) This would be a ninety degree movement. Feed your subjects candy bars to give them some controlled caloric intake. Record the amount of calories in the bar as listed on the wrapper (there will be a source of error here since the bar wrappers record only average number of calories). If you want to use different caloric amounts, use different samples of the bars (or some other carbohydrate snack). Remember to keep using the same type of bar, though. You can use honey, too, if you measure it out carefully. Look in a recipe book for the number of calories to the teaspoon of honey. Do the muscle action measurements before and after calorie intake. Do them in increments of 10 minutes. If you choose to take several readings, for example, every ten minutes, be sure to take a measurement for only a short period of time, like one minute. That way the muscle is not fatigued to the point of exhaustion. Not everyone will react the same way. Try to determine the limits of action and what it is dependent upon: age, caloric intake, previous workouts, etc.

Materials Strength

29. You can determine the maximum height possible for an unsupported board with a fixed weight sitting on the top. If the board is any taller, it will bend, collapse, or crumble because of instability.

This test can actually be tackled from two directions. You can add weights to the top of a board until it bows, or you can use increasingly longer boards until the board is too long to support the weight attached. In each case the theory is the same. In building a house, the vertical strength of a board is the important factor in holding up a wall or the second floor.

This experiment can be done with balsa and pennies. Put the bottom of a balsa slat in a secure position and glue it down. The balsa slat should be of smaller crossection than a penny's diameter. Hot glue a penny on top. Gradually increase the length of the board (by setting up the same situation with a different board) until the weight of the penny is too much for the board. If your balsa is strong you may have to use several pennies.

Record the length of the board at failure and the weight of the mass atop the board. At this point you can try several things. Aways remember, though, that you must do several trials of each test in order to establish a numerical relationship between length and weight.

A ratio of length to weight supported would be an interesting outcome. You could test the universality of the ratio by expanding your testing to other types of woods. In order to do this you will have to cut pieces of woods which are the same size as the original balsa you tested. The crossectional area will have to be kept constant.

30. Another approach at this point would be to vary the crossectional area of the board. The thinner the board the less weight it should be able to support. You will be quickly aware of the obvious reasons to use steel in building construction if you will test a length of a steel rod, for example (or a nail).

31. Is a log (a round board) stronger than a rectangular one? This could be tested in much the same way as the previous questions. Remember to keep the crossectional area constant.

32. An idea which is an offshoot of the one above is based on the observation that horizontal branches are stronger than more vertical ones. It seems that the cells underneath the junction of the trunk and the limb develop thickenings which strengthen and support the limb. The more horizontal the limb the tougher the supporting cells beneath the limb. So, in heavy storms, the more vertical limbs are usually the ones which go down.

Now, to test this observation, you will need a woody plant with plenty of small branches. You would measure the angle made between the main stem and the branch and record. Then test the theory by suspending weights to the branch until it breaks. Record the weight necessary to break the branch. Plot the information on a graph using the angle of the branch as the independent variable on the x-axis and the weight to fail as the dependent variable on the y-axis. If you could make up some microscopic slides (wet mounts only) , you would really round out your project. Photos of your findings would probably give you a chance for the usual photographic awards at the science fair. Don't use your mother's favorite shrubs for this experiment.

33. To test the strength of materials, engineers test to destruction the construction material. To test to destruction, or failure, means to stress with weights, for example, a structure, until it breaks. This testing is important to any type of building, but especially to aircraft and automobiles.

Bolts can be tested to see if the heads can be shorn off. Since there are many different types of bolts, you should choose one size and test different brands of that size.

Some variables are: the location of manufacture, materials used in the construction, method of construction of the bolt. You could relate the strength of the bolt to the price. The stress on the bolt can be measured by the amount of force required to shear off the head.

The force can be applied as follows: Clamp the threaded end of the bolt in a vise. Use a vise grip or something similar to hold onto the head. Suspend weights from the grip. At some point the head of the bolt will twist off. The failure point is also dependent upon temperature since metal is softer at higher temperatures. If you had time, you could test this variable, too.

34. Hacksaw blades are different from each other in construction and in ability to hold up under heavy use. You could test multiple brands of hacksaw blades by attempting to saw the same distance in metal while others count the stokes required to cut the equal length of metal.

There are a few variables which you will have to hold constant. These variables include pressure on blade, speed of cutting, etc. You will need to be as precise as possible on these variables. You could place weights upon the end of the hacksaw handle so that the pressure exerted downward is constant for all the blades you test. Make sure that the materials you are sawing through are all the same. Each brand of blade will have a different number of strokes to reach the same point of sawing, whether all the way through a bolt or halfway through a pipe.

35. You can determine the bursting strength of chip packages, ketchup packets, or hot sauce bags.

This could have interesting results when the bag bursts, so prepare your testing platform well. You can do this with ziplock bags, but they would not be as much fun as the filled bags during catastrophic failure. Use progressively larger weights to test the bags. Better try several of each type to get an average and smooth out your curves on your chart. Variables which would affect your results may be: temperature of the bag, temperature of the weights, flaws in the bags, substance within the bag, and speed at which the weight is applied to the bag.

36. Perform a stress analysis on paper towels by suspending the towel from four points, or along two sides, and place weights on the toweling increasing the weights until the towel breaks.

This may be done wet, also. For weights, you could use Lego-type blocks, or marbles, of the same size. The use of fibers in the towel should strengthen it. Make many tests so that you have lots of data to plot on your charts. Hypothesize about how to improve the strength, and test the hypothesis by making some towels which meet your specifications. This will make your project different from others using this classic project. You will be asked "What difference will strength make in a paper towel?", so have your answer ready before the science fair. Another way to do this experiment is to use some other product, like disposable diapers. This product must hold up while wet so test it both ways.

Rocket Stability

37. Rocket stability is dependent upon the fins which keep it moving in a straight line. You could determine the effect of different fin designs/materials on rocket stability and altitude attained. This sounds like the classic nosecone experiment but it really isn't. The fins you use could be made out of unusual materials: feathers, triangular ridges extending down the body tube of the rocket, or flexible plastic fins hot glued on. How about fish fins glued on? You can surely come up with some really good ideas.

After you have made your models, you need at launch them and record their characteristics of flight: do they roll, wobble, tumble, go completely out of control? Remember to record the height of the rocket. Your Estes manual will tell you how to measure this if you choose not to buy the altitude measuring device they sell. All it takes is a stick with a protactor attached to it from the point of the origin of the protractor. Tape a straight edge on the straight side of the protractor. Place the upright stick into the ground vertically 100 meters from the launching point. As the rocket is launched, track it with the straight edge by sighting along the straight edge. When the rocket reaches its highest point, hold the straight edge and protractor still and read the number of degrees of the angle shown by the protractor. The angle is that measured between the vertical upright stick and the end of the protractor closest to you. (an acute angle) Now you know the distance to the launch point and the angle at which the rocket looks down towards you. This is called the angle of declination or angle of depression. Make a triangle with the three points: launch point, you, and the peak of flight of the rocket. Using trigonometric functions, solve for the altitude of this right triangle. In your conclusion, be sure to hypothesize about why you think the fin changes did what they did to the flight of the rocket.

Burning Wood

38. Burn equal-sized plugs of wood and try to determine if the location on the wood in the tree causes a difference in the quality of burning. For example, the heart may burn longer than the wood from just under the bark.

Measure the mass of the plugs to give you the necessary data to calculate the density of the wood in the plug. You can measure the length of time necessary to burn the plug to ash. Record other factors such as the color and density of the smoke and the color and density of the flames. You should be able to chart the relationship between the time to burn completely and the density of the wood. This has an impact upon the use of wood in wood stoves and in furnaces, a method used frequently overseas as well as here. If you are industrious you could determine the number of calories produced during the burnings by building a homemade calorimeter. Granted, the device will not be as accurate as a professional one, but try to improve it as much as possible.

39. Compare wood burning to oil, wax, paraffin, shortening, etc. as to how much light is given off. You could use a light meter to determine light strength. You will need to have a standard light source in order to calibrate your light meter.

Another way to measure this is the double paraffin block method. With rubber bands, bind two paraffin blocks together with a piece of cardboard between them. If you place the block between two sources of light (only two), you can determine which is the stronger, or you can measure by foot candles the source of light. When you are using two sources of light, one on each side of the blocks, the paraffin will glow a lighter shade on the side with the stronger light source. It is reasonably accurate and certainly sufficient for your purposes.

To compare a light source to determine the number of foot candles it is putting out, place the blocks in the center of a ruler. On one side, at a foot from the block, place a candle which has been lit. Place your unknown light source on the other side. Move the unknown light source towards or away from the blocks until the blocks glow with the same amount of the light. At this point, measure the distance to the blocks from the unknown light source. Using the Inverse Square Law, you can find the intensity of the unknown light source.

$$i \times d^2 = i_2 \times d_2^2$$

where i is the intensity of the light source and d is the distance as measured on the ruler.

Oil Effectiveness

40. The effectiveness of oils to lubricate can be tested. You can use blocks, cars, etc. Devise a track for your cars. A board on an incline is sufficient. Standardize it by using a car with no lubrication. Measure the distance the car travels down the ramp and across the floor. Use different oils on the cars and do not forget to use mineral oils as well as animal oils and fats. You can use petroleum jelly, nut oils, honey, grease, sewing machine oil, butter, etc.

Polishing Compound Effectiveness

41. Measuring the effectiveness of polishing or polishing compounds using the reflectivity of light of the the polished object is the traditional method although highly subjective: "It's so shiny you can see your face in it." There is a method of measurement used by astronomers to check the accuracy of their mirror polishing since a less than perfect mirror will have flaws in the viewing.

If you use a light meter to measure the reflectivity of light from the surface of a polished object, you will have a similarly accurate method to determine polish effectiveness. Using this method you could test the effectiveness of various polishing agents.

42. Another experiment along similar lines is to measure the polishing effectiness of different techniques. Suggested styles of polishing are circular and longitudinal.

Fractals

43. Using fractals, it is possible to create forms which really look like plant foliage or a rocky landscape. Some scientists believe that the DNA code actually hides an equation for a fractal set which becomes a physical reality as the plant grows.

Can you compare fractal data to real life to determine basic genetic/ biological factors involved in the life? In other words, are there factors which will determine the growth pattern for a crystal or for a leaf, or for a tree? Yes, there obviously are, but can you isolate a factor, transform it into equation form and create a fractal for it? A clean, cubic crystalline shape may be the easiest equation to use.

44. Another idea in this area is to construct an equation set which makes a pattern resembling a pre-existing life form. This would be doing something similar to the idea above, but in the opposite direction. This time, start with the equation and go to the life form.

These two ideas are somewhat advanced, but a curious student can solve a lot of questions.

Computer Programming: Error Detection

45. The effect of random factors and error correction in data streams can be simulated with a computer program.

Using a computer, write a program which simulates a data connection. You could construct a data stream which would be similar to the four acid code in DNA. You can also construct self-correcting files (an error correction protocol) within the system which would tend to restore the file to its original message. Even basic survival is a type of data cleaning tool. Mutations which are beneficial are rare genetic structures which become part of the system as "correct" errors in the information. These so-called correct errors pass into the life chain by being a correct error.

In your computer simulation, you could use an artificial organism and attempt to predict possible changes. How could environmental factors effect the formation of these error messages? What factors could influence the formation of correct errors?

How much of a packet of information transmitted through space, for example, could be kept clean, or corrected upon reception?

Chocolate

46. Chocolate candy will melt at relatively low temperatures; body temperature, for example. Could a recipe be concocted for milk chocolate which would not melt at such a low temperature? Even withstanding desert-like conditions? In 1991, Hershey's advertised for just such a chocolate recipe. I do not know if they were successful. In addition, your chocolate should taste reasonably good.

Natural Pigments

47. The Native Americans used natural ingredients to make pots and the glazes to decorate them.

See if you can duplicate the pigments yourself. Ask the experts at a local museum to evaluate your products. Use an artist's color wheel to quantify the pigmentation, or invent your own. Remember that the colors must be fired at similar temperatures as the firings of the Native Americans. This means that if you fire your pots you may have to use early techniques. For example, you may dig a hole and build a fire in it in order to bake your pot.

The problem with this idea is that it does not easily lend itself to quantification. You do not end up with numbers which you can chart automatically. It can be quantified, though, by using some homework. You will need to know the components of the clays and/or pigments. The percentage of clay, for example, can be recorded. The strength of the pot can be measured and compared to the length of time of firing and the temperature of the oven. This has the potential of being an excellent problem.

Brine Shrimp and Pond Organisms

48. The small organisms called brine shrimp will react to various stimuli. Ultraviolet light, strong light of other wavelengths, heat, and cold all cause the brine shrimp to respond. You can observe and measure their responses.

You will need a microscope, some depression slides, a dropper, and a jar of hatched brine shrimp. Use unexposed shrimp as your control. Observe the reactions like avoidance, death, change of color, change of motion or mobility. Be sure to record the length of time exposed to the stimulus.

49. The living organisms within a pond grow and reproduce according to rules which apply to all living things. Changes in the environment can change the rates of growth and reproduction of the organisms. If you have access to a pond, a microscope, and a few slides, you can do some very interesting ecological studies.

Suggested questions to investigate are: How does the pollution in the pond affect the living organisms of the pond? You will have to find an unpolluted area of your pond to use as a source of the control organisms. Also, you should remember that not all forms of pollution are detrimental to life. Thermal pollution, for example, can promote the expansion of a population by providing a warm environment.

50. How does the depth of the pond affect the types of organisms living in it? (Other influencing factors can be light penetration, temperature, presence of silt) Your control must be similar to the variable environment except for only one factor, for example, temperature. Observe the types of organisms, recording their numbers, size, and other characteristics which may be affected by the change in temperature (or other variable).

Note: Remember that each pond is different from any other. Two ponds or lakes, side by side, can have totally different habitats.

A Final Word

Any or all of these experiments could be changed to meet your specific needs. Each of them has additional experiments, related to it, which would also be of use to an inquisitive student.

Ask Questions.

Maybe no one knows the answer.*

You may be the first to find out.

** If no one really knows the answer, you can still get help to work the experiment. When someone does not know the answer to your question, he or she can still help with methodology.*