SAB WORKSHOP II ON STEPS TO A GOOD SCIENCE FAIR PROJECT

EXPERIMENTATION AND RESULTS

THE SCIENTIFIC METHOD:

There Are Different Forms of the Scientific Method:

Not all fields of science arrive at conclusions in the same way.

The physical sciences, like physics and chemistry, use experimental forms of the "scientific method." The physical sciences do experiments to gather numerical data from which relationships are derived, and conclusions are made.

The more descriptive sciences, like zoology and anthropology, may use a form of the method that involves gathering of information by visual observation or interviewing.

What is common among all sciences, however, is the making of hypothesis to explain observations, the gathering of data, and based on this data, the drawing of conclusions that confirm or deny the original hypothesis.

What is the Experimental Scientific Method?

Experimentation is the process of testing a hypothesis.

STEPS IN DOING AN EXPERIMENTAL SCIENCE PROJECT

The steps in the experimental scientific method as usually presented are: Observation, Hypothesis, Controlled Experiment, Data analysis and Conclusion.

Check list before starting experiments:

1) Initial Observation

You notice something, and wonder why it happens. You see something and wonder what causes it. You want to know how or why something works. You ask questions about what you have observed. You want to investigate. The first step is to clearly write down exactly what you have observed.

2) Information Gathering

Find out about what you want to investigate. Read books, magazines or ask professionals who might know in order to learn about the effect or area of study. Keep track of where you got your information from.

3) Title the Project

Choose a title that describes the effect or thing you are investigating. The title should be short and summarize what the investigation will deal with.

4) State the Purpose of the Project

What do you want to find out? Write a statement that describes what you want to do. Use your observations and questions to write the statement.

NOW YOU ARE READY TO START THE EXPERIMENTS:

GUIDELINES FOR EXPERIMENTAL PROCEDURES

Procedure

Write down the procedure:

Give a detailed explanation of how you will conduct the experiment to test your hypothesis.

To design a suitable experiment you must make an educated guess about the things that affect the system that you want to investigate. These are called **variables**.

> There are three kinds of variables that you need to identify in your experiments: independent, dependent, and controlled.
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> The **independent variable** is the variable you purposely manipulate (change). The **dependent variable** is the variable that is being observed, which changes in response to the independent variable. The variables that are not changed are called **controlled variables**.
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> For example, if the problem concerns the effect of light on the reproduction of bread mold - The independent variable for the experiment is light and the dependent variable is bread mold reproduction.
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> Select only one thing to change in each experiment. - Change something that will help you answer your questions. If you change more than one at a time, you will not know what variable is causing your observation. Sometimes variables are linked and work together to cause something. At first, try to choose variables that you think act independently of each other.

You should include a regular timetable for measuring results or observing the projects (for example, every hour, every day, every week).

Controls:

> For an experiment to give answers you can trust, it must have a "**control**." A control is an additional experimental trial or run. It is a separate experiment, done exactly like the others. The only difference is that no experimental variables are changed. A control is a neutral "reference point" for comparison that allows you to see what changing a variable does by comparing it to not changing anything. Without a control you cannot be sure that changing the variable causes your observations. A series of experiments that includes a control is called a "controlled experiment."

Your procedure should be like a recipe - Another person should be able to perform your experiment following your procedure.

Ask a teacher/parent/ scientist to go over your procedure with you.

Does your work involve chemical/biological hazards or animal or human subjects?

Make sure you have the necessary forms filled in and approved.

OBTAIN MATERIALS AND EQUIPMENT

Make a list of the things you need to do the experiment, and prepare them. You may need to contact professional institutions for special equipment, expertise and working environment.

DO THE EXPERIMENTS AND RECORD DATA

Experiments are often done in series. A series of experiments can be done by changing one variable a different amount each time. A series of experiments is made up of separate experimental "runs." During each run you make a measurement of how much the variable affected the system under study. For each run, a different amount of change in the variable is used. This produces a different amount of response in the system. You measure this response, or record data, in a table for this purpose. This is considered "raw data" since it has not been processed or interpreted yet. When raw data gets processed mathematically, for example, it becomes results.

As you do experiments, record all numerical measurements made. Data can be amounts of chemicals used, how long something is, the time something took, etc.

Record Your Observations

Observations can be written descriptions of what you noticed during an experiment, or problems encountered. **Keep careful notes of everything you do, and everything that happens.** Observations are valuable when drawing conclusions, and useful for locating experimental errors.

Repeatability or reproducibility:

Experiments are often done many times to guarantee that what you observe is reproducible, or to obtain an average result. Reproducibility is a crucial requirement. Without it you cannot trust your results. Reproducible experiments reduce the chance that you have made an experimental error, or observed a random effect during one particular experimental run.

PERFORM CALCULATIONS

Do any calculations needed from your raw data to obtain the numbers you need to draw your conclusions. For example, you weighed a container. This weight is recorded in your raw data table as "wt. of container." You then added some soil to the container and weighed it again. This would be entered as "wt. of container + soil." In the calculation section, do the calculation to find out how much soil was used in this experimental run:

(wt. of container + soil) - (wt. of container) = wt. of soil used

Each calculated answer is entered into a table in a Results section.

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

SUMMARIZE DATA

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

Graphs

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

Different types of graphs are appropriate for different experiments.

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

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

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

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

Be sure to label the axes of your graph--don't forget to include the units of measurement (grams, centimeters, liters, etc.).

INTERPRET RESULTS

Studying tables and graphs, we can see trends that tell us how different variables cause our observations. Based on these trends, we can draw conclusions about the system under study. These conclusions help us confirm or deny our original hypothesis. Often, mathematical equations can be made from graphs. These equations allow us to predict how a change will affect the system without the need to do additional experiments.

DRAW CONCLUSIONS

Now is the time to pull together what happened, and assess the experiments you did. Using the trends in your experimental data and your experimental observations, try to answer your original questions. Is your hypothesis correct?

If your results support your hypothesis:

You might say, for example, "As stated in my hypothesis, I believe that light is not necessary during the germination of bean seeds. My experimentation supports the idea that bean seeds will germinate without light. After seven days, the seeds tested were seen growing in full light and in no light. It is possible that some light reached the 'no light' containers that were placed in a dark closet. If I were to improve on this experiment, I would place the 'no light' containers in a light-proof box and/or wrap them in light-proof material, such as aluminum foil."

If your results do not support your hypothesis:

It is perfectly ok to have a project where your results don't support your hypothesis. So,

DON'T change your hypothesis.

DON'T leave out experimental results that do not support your hypothesis.

DO give possible reasons for the difference between your hypothesis and the experimental results.

DO give ways that you can experiment further to find a solution.

Other Things You Can Mention in the Conclusion

If your hypothesis is not correct, what could be the answer to your question?
Summarize any difficulties or problems you had doing the experiment.
Do you need to change the procedure and repeat your experiment?
What would you do different next time?
List other things you learned.

EXPERIMENTAL ERRORS

If you did not observe anything different than what happened with your control, the variable you changed may not affect the system you are investigating.

-If you did observe a difference one time and not the other (inconsistent), there is no reproducible trend in your series of experimental runs.

There may be experimental errors affecting your results.

The first thing to check is how you are making your measurements. Is the measurement method questionable or unreliable? Maybe you are reading a scale incorrectly, or maybe the measuring instrument is working erratically.

If you determine that experimental errors are influencing your results, carefully rethink the design of your experiments. Review each step of the procedure to find sources of potential errors.

Random Errors

If your measurement method is not the cause, try to determine if the error is systematic or random. Random errors are more obvious. They result in non-reproducible data that doesn't make sense. In this case, runs with the same combination of variables, and even the control itself, cannot be duplicated. Some randomness is always present in nature. No two measurements are exactly the same.

A random error may be occurring because you are doing something differently in each run. For example, you are not careful in cleaning your reaction vessels and some of the chemicals are being carried over from the last experiment.

Systematic Errors

Systematic errors are harder to find. Your data and results may look consistent and reproducible. Here you may be doing something you are not aware of that is causing all your measurements to be off the same amount. For example, if you were not aware that a piece of your ruler had been cut off and now starts at 2" instead of 1", all your measurements would be one inch too long. This is a systematic error because all your data is affected the same amount, and in the same direction.

Prepared for the SAB
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From GSDSEF website:

Computing & Mathematical Sciences projects

These may be an engineering-type project focussed on hardware or software development. This division also includes projects that deal with mathematical models or which have used mathematics to solve theoretical problems. Projects that use computers just to store and manipulate data should be exhibited in the division suggested by the nature of the data. If the focus is an innovative way to use the computer or mathematical model, then the data is secondary and the project should be entered in Computing or Mathematical Sciences.

Guidelines for Computer-Oriented Science Fair Projects

Computer Science - Study & development of computer hardware, software engineering, internet networking and communications, graphics simulations/virtual reality or computational science (including data structures, encryption, coding & information theory).

Computer technology may be incorporated into science fair investigations in one or a combination of the following three ways:

As a tool to record/statistically analyze data gathered in another experiment

A. Projects of this type would be entered in the category of the experiment involved.
B. State whether the student wrote the program used, made a major adaptation of an existing program or used already available software. If the program is the original work of the student, that part of the project should be presented as outlined in III below.

Developing/building new computer circuits/hardware items

A. Project would be entered in the Engineering category.
B. If the software/firmware programs are the original work of the student, they should be presented as shown in III below.

Writing a new computer program/software development

A. Project would be entered in the Computer Science category.
B. A project of this type should include:
1. A statement of the student's OBJECTIVES. This should include a description (the configuration) of the computer system that will be used to achieve those objectives and of the system's capabilities.
2. A summary of the research done by the student before writing the program. What else has been written/programmed about this topic. State why this new program will be different/better/more useful.
3. A chronological description of the development of the program. It should describe the various approaches tried and explain why they were accepted/rejected.

4. A concise block diagram or similar presentation to show the structure of the program design (maximum of two pages) and that it is cross-referenced to the program listing (#5 below).
5. A program listing that includes explanatory remark statements and is cross-referenced to the block diagram (#4 above).
6. A sample run(s) to show the product(s) of the program.
7. A critique of the completed program showing how well the objectives were achieved and/or how the program is qualitatively different from or better than other similar programs.

Math Projects

Mathematics - Development of formal logical systems or various numerical algebraic computations and the application of these principles-calculus, geometry, abstract algebra, number theory, statistics, complex analysis, probability.

Math Project Guidelines:

The first and most important step is to come up with a project idea which is achievable. Discovering a previously unknown result or formula would be the ideal Mathematics project. However, a new approach to deriving or obtaining a known fact, or a new way of looking at a known concept are also perfectly acceptable ideas. Topics from newer branches of mathematics such as Fractals, Fuzzy Sets, Chaos, and Game Theory are well within the capabilities of high school students and offer a relatively untapped resource for project ideas. Looking through recent books, journals and magazines can also provide ideas. Students can talk over these ideas with their math teachers, parents, and other students to clarify their approach. Simply performing an experiment and tabulating results (e.g. counting the number of heads which occur in N flips of a coin) does not rate highly. Analysis of experimental results, including computing means and variances, makes a better project. Computers can be used to help analyze data when appropriate.

After the idea has been formulated, it should be researched to determine whether the project has already been done, or whether the approach is already known. Repeating a project which has already been done does not rate a very high score. For example, tabulating coin flips, dice rolls, the Pathagorean Theorem, Pascals Triangle are well worn ideas. Students should talk to their teachers or consult previous Science Fair programs to see whether they are repeating old projects. Once the student is satisfied with the originality of the project, research should be performed to find all known facts related to the project idea.

The next step is to derive or calculate the results. This is usually the most time consuming part of the project. Originality and innovation during this step will result in higher scores for the project.

Finally, the project must be written up and a project display produced according to Science Fair guidelines. The project write-up and display should include the following items:

1. A statement of the objective - a clear description of the main idea of the project.
2. A summary of the research done to find previous related results.
3. A statement of what is new, better, or different from previous results.
4. Details of the development of the project.
5. A statement of the results or conclusions.
6. A critique of the results and ideas for future research or extensions of the results.

An Engineering project applies physical science knowledge to solve a problem or achieve a purpose. Engineering projects investigate the utility of innovations and inventions.

Engineering projects directly apply scientific principles to manufacturing and practical uses -civil, mechanical, aeronautical, chemical, electrical, photographic, sound, automotive , marine, heating and refrigerating, transportation environmental engineering, etc.

Although a complete engineering project will include an outline of the need, the development of the innovation and some work on introducing the innovation to the community, many projects focus on just the development phase.