WORKING WITH THE NOVICE SCIENCE RESEARCH STUDENT INSIDE OR OUTSIDE THE CLASSROOM

CHAPTER ONE: JUST THE BEGINNING

“Where Do I Start???”

THIS IS THE BIG ONE! Some students will have a question or problem in mind right away, but most beginning researchers will need help deciding on a topic. What does the student like to talk about, see or do in the fields of science, math, or technology? The teacher will need one-on-one time with the student, in a relaxed setting inside or outside the classroom, to help the student determine or discover several areas of interest. Appendix E lists materials which offer a multitude of suggestions.

As a starting point, the ISEF (International Science & Engineering Fair) breaks projects down into the following categories: Animal Sciences, Behavioral and Social Sciences, Biochemistry, Cellular and Molecular Biology, Chemistry, Computer Science, Earth and Planetary Science, Engineering: Electrical and Mechanical, Engineering: Materials and Bioengineering, Energy and Transportation, Environmental Management, Environmental Sciences, Mathematical Sciences, Medicine and Health Sciences, Microbiology, Physics and Astronomy, and Plant Sciences. For details, including subcategories and descriptions, go to http://www.sciserv.org/isef/students/research_categories.asp#BE

Even where the child thinks he knows what field he wants to explore, he may have to do a background search first to determine a solid research question in the chosen topic area or to validate the known current question. The student wants to be sure that the question has not already been answered by scientists and that it is a question on which information can be gathered.

Right from the start the teacher needs to reassure the student that it is the effort, and the process of following the scientific method to completion, that count, NOT whether their research produces the expected results. We all learn from our mistakes and children need to know that they too can use mistakes or failures as building blocks to accomplish more than they ever expected. “Risk-taking” is a frightening thing for a young mind, but once given approval to investigate, regardless of the results, a student will become a more confident, self-determined individual.

As one of our famous “ADHD” scientists said,

“I’ve never made a mistake, I’ve only learned from experience.”

Thomas Alva Edison
“What Is My Topic?”

The student needs to do some background research and read a number of published articles or abstracts regarding the areas of interest identified at the first meeting. The goal here is to focus in on one or a few specific topics the student finds particularly intriguing. Be sure the student keeps a list of the sources he or she uses at this point; these will form the basis of the final Bibliography. The final project must include a minimum of six (6) valid, professional sources for the topic finally selected for research.

“What Is My Problem, or Question?”

The student should now meet with the teacher for a second time to discuss the materials read and to determine if a specific point of interest was found or if more ideas need to be pursued.

The student is now at one of two points:

a) He or she has a definite area of interest, which means the teacher will help the student search the internet for meaningful articles and develop a specific problem or question for the student’s research. Hopefully this can be accomplished by the end of the second meeting.

b) The student is still not certain of his or her topic area. During this second meeting the teacher needs to make some specific suggestions from the areas most interesting to the student, offering a choice from two or three research ideas and asking the student to choose one. The teacher should remind the student that if the chosen area does not work out, they can start over with a new choice. The ability to change research topics or procedures may be an option, given enough time; otherwise, if time is limited, use the information gathered to show what has been learned by the research student. One very tenacious former student (now a Yale graduate) had to resort to the latter many times, but never gave up research of the unknown. In this way the student feels less risk in choosing a research topic.

From either (a) or (b), a research topic and a problem or question have now been decided. The student is now ready to work with the steps in the Scientific Method.
STEPS OF THE SCIENTIFIC METHOD

(As used in Independent Research at Canterbury School)

1. State the Problem (Question)
2. Make Observations AND Write a Background Report using APA citations
3. Form a Hypothesis
4. Write the Procedure (Protocol)
5. Conduct the Experiment (or meta-analysis research)
6. Record the Data
7. Analyze the Data
8. Draw a Conclusion

This may sound rather boring for the student. The teacher needs to step in again here with words of encouragement and excitement over the student’s ideas, and then help to direct those ideas in a direction that will ensure success for the student.

Following are some Teacher Response Behaviors that may be useful, suggested by Arthur Costa:

- Facilitating wait time
- Acquisition of data
- Nonjudgmental acceptance
- Clarifying when needed
- Modeling congruent behavior with cognitive goals and objectives with the goal for student to imitate behavior (Costa, 1994)

The transfer of learning and thinking behaviors can be summarized:

Passion + Habit = Love for Scientific Research With No Boundaries or Limits placed on their Learning = Production of High Achieving Students
There is a strong connection between a structured educational environment linking passions for learning and thinking, with habits of the mind and their transfer. (Perkins & Salomon, 1988)

**STEP 1: STATE THE PROBLEM**

The problem starts when you ask a question about something that you observe: How, What, When, Who, Which, Why, or Where. In order for the scientific method to answer the question, it must be about something you can measure, preferably with a number.

A preliminary problem or question should have been achieved following the instructions in Chapter One. Please remind the student that this “working problem” is subject to change and can be reassessed as the research proceeds.

“The formation of a problem is often more essential than its solution, which may be merely a matter of mathematical or experimental skill. To raise new questions, new possibilities, to regard old questions from a new angle, require creative imagination and marks real advances.”

*Albert Einstein*

**STEP 2: OBSERVATIONS, SOURCES, AND BACKGROUND REPORT**

Now that the student knows the major question in their research, a background report is the next big step for the student.

A research scientist combines physical observation with the use of library and Internet research sources, to help find what is currently known on the chosen topic. This will help determine the best way to proceed and insure that the scientist does not repeat mistakes or successes from the past. Internet searches should be current through the month you are working in, while doing the search. Be sure that you are not conducting research that has already been accomplished and statistically proven scientifically correct (or incorrect!). You may do research in areas where current research does not show statistically significant proof of accurate data leading to accepted, scientifically valid and reliable fact; you need to state such lack of current significant proof, citing sources, in the background paper.

This report must run at least five (5) pages, size 12 font, double spaced, using APA style for references. There should be at least six (6) references to the ISEF hand book, and for the beginner, six (6) other current (most recent years) sources from books or the internet. Research protocol (procedure) is not to be started until the student has checked current (in the past year) publications on professional research in the topic area.
At this point the teacher will schedule a third one-on-one with the student, reviewing the student’s sources and personally going to professional sites to add a thorough review of the topic to the student’s reference list, for later reading and inclusion by the student.

**THE FORMULATION OF RESEARCH PROTOCOL**

**STEP 3: HYPOTHESIS**

*“What do I think that my research, after experimentation and data collection, will demonstrate?”*

A hypothesis is an educated guess about how things work: “If ___ [I do this] ___, then ___ [that] ___ will happen.” It is based upon current knowledge (from past education and research performed for the background report).

State the hypothesis in a way that can be easily measured. The hypothesis should be constructed in such a way that it will help answer the original question. The experimental results may prove the hypothesis wrong, which means you will then conclude with an alternate hypothesis.

**STEP 4: WRITE THE PROCEDURE (PROTOCOL)**

*“How do I carry out my research?”*

Now comes the time during which the teacher offers the student unconditional acceptance, with ongoing support throughout the writing and performing of the research.

The procedure, or protocol, describes how the student will carry out the research. This will be a joint effort between student and teacher, with the teacher editing and adding essentials not yet known by the student. It is time for another one-on-one – this may be the 4th, 5th or 6th meeting, depending on how smoothly the previous steps have gone.

The procedure will be outlined first and then re-written for every detail, including any materials used and at least six (6) rules cited from the ISEF Rules Book. This may take over a week, with the teacher proofreading and giving suggestions at each edition. It is ideal to have all work e-mailed to the teacher, at this point, since it is easier to read and more efficiently
corrected by the teacher. Yes, the teacher should make corrections, asking the student to complete any lengthy additions.

**STEP 5: EXPERIMENT/RESEARCH & ISEF Paperwork**

This is when the student conducts the experiment or research (inc. meta-analysis research).

In performing the research, the student needs to follow each step, as described in the written procedure, and record in a daily log book what was completed and/or found different that day. Depending on whether there are live organisms, pathological organisms, dangerous chemicals or equipment, each procedure should have been designed to address safety at all levels of research. Of utmost importance, is the reading over and over the section of the ISEF which relates to your project. Every requirement for your subject, in the handbook, must be followed and described with results and disposal (if required).

The student needs to update the teacher at each point of any change in research, with a weekly log update sent by attachment to the teacher. All student work will be kept in an electronic folder by the teacher.

At any point, if the student does not understand or is alarmed, the teacher should be told ASAP, while following all safety guidelines reviewed and signed by the student.

**STEP 6: DATA COLLECTION**

Throughout the process of doing your science fair project, you should keep a journal containing all of your important ideas and information. This journal is called a laboratory notebook. All data collected should be recorded on dated pages with times for the findings (also see Step 5).

Data management is critical for appropriate and effective utilization and analysis, showing if the data supports the hypothesis. Data collection can range from basic to complex. The following are some examples:

Data from any basic experiment where information is collected

Plant growth measurement in the metric system
Cell data for specifically stained cell parts

Pollution data for air, using scientific test kits or live organisms

Water test data for pollution by specific chemical elements, pathogens, death of organisms

Invertebrate reactions data, physically or physiologically to different stimuli or environments

Electromagnetic energy data, as it affects or is effected by different materials

Data collected and placed on a spreadsheet from human questionnaires or for human physiological measurements over time

Data from meta-analysis of remotely-sensed or in-situ observations in the earth and space sciences

Data from meta-analysis of seismic sounding of the earth for petroleum geophysics (or similar signal processing endeavors in acoustics/oceanography, radio astronomy, nuclear magnetic resonance, synthetic aperture radar, etc.)

Data from meta-analysis large-scale supercomputer-based studies in computational fluid dynamics (e.g., aerospace, meteorology, geophysics, astrophysics), quantum physics and chemistry, etc.

Data from meta-analysis of medical (tomographic) imaging records (e.g., CAT, PET, MRI) under variable psychological or physical environmental conditions

Data from experimentation using genetic sequence mapping, etc.....
STEP 7: DATA ANALYSIS

The first step toward understanding and interpreting scientific data is to place the data in a form that can be visualized, such as charts, graphs, and spreadsheets.

The next step is to gain a quantitative understanding of the data using some form of data analysis. This step can involve simple mathematical data comparisons, percentiles, average distribution around the mean, spreadsheets followed by finding the mean, mode, average, distributions percentiles, T tests and correlations. More advanced analysis might include learning about random events, games of chance, mathematical and experimental probability, tree diagrams, the binomial probability model, numerical and graphic representations of the minimum, the maximum, the mean and median, probability quartiles and measure variation about the mean, and a box plot. Other choices for analysis could possibly use: Analysis of bivariate data and the association and co-variation between two quantitative variables. Also scatter plots, the least squares line, and modeling linear relationships.

The above naming of statistical possibilities will mean nothing unless the student has planned from the start of the research, the type of data to be collected which will fit the analysis required by the research. (Uitenbroek, D. G., 1997)

To assist the students to perform the more advanced statistical analysis of their data, high school and college math teachers are available. We also have college assistance in using the SPSS program, for which you need only your spreadsheet. Below I have also listed free online statistical help sites. The analysis is one of the most important steps in research, for it will show whether the hypothesis was correct. If the hypothesis is shown to be incorrect, the data analysis will support an alternate hypothesis.

STEP 8: CONCLUSION

In the conclusion, you answer your problem or question.

Make your sentences clear, concise and to the point.

Explain why, if you were to do your experiment again, you may or may not get the same results. If they could be different, what factors might cause the differences?

Did your results support the hypothesis? Explain why or why not, in as much detail as possible, which will support your opinion.
If the results did not support the conclusion, tell why you chose the alternate hypothesis and what you could do to validate further support of the alternate hypothesis.

Near the end of your conclusion be sure to state why you think this research was important to the scientific community and to society at large.

Source: Getting Students Started in Scientific Research  Betsy Glass, Ph.D., 2007