

The guide below details information for science fair from a student perspective, including details of how to choose a project, the journal, board, and judging process.

The guide was designed by Mirae Parker, Michelle Wei, Bovey Rao, Naveen Rathi, Brandon Cui, and Nityam Rathi, who were all members of the 2013-2014 Salt Lake Valley Science and Engineering Fair Student Advisory Board.

Best of luck to all of you!

Why Science Fair

Each year approximately 7 million students participate in Science Fairs¹. Why? Science Fair is the primary method for precollegiate students to engage in scientific and engineering research and study. Science fairs across the country give students the opportunity to win awards and recognition for their work, which in turn help with college admissions. Most of all science fair provides the bridge for high school, Jr. high and elementary school kids to apply the knowledge and skills they are learning in the classroom to real world dilemmas, ensuring they have the ability to grapple with the world's challenging issues of tomorrow.

Choosing a Project Idea

Choosing a good project idea is critical to the science fair experience. It is important that you choose something that is interesting to you, and reasonable. Interested in Mars Rovers? Rather than building your own rocket-ship to Mars, find a small part of the robotic system you can build and test at home! There are a multitude of excellent resources available for coming up with project ideas. Science Buddies (http://www.sciencebuddies.org/science-fair-projects/project_ideas.shtml) is a great place to go to get some ideas, as is talking to teachers/parents/friends. Please check and make sure that your project meets the following standards:

- **Safe!** ISEF has specific guidelines for these materials. The exact rules for students working with vertebrate animals, human participants, hazardous chemicals, or biological materials can be found in the following link along with general rules for the science fair: <https://student.societyforscience.org/international-rules-pre-college-science-research>
- **Affordable!** There are so many fantastic projects out there that won't cost you a lot. You can still do original projects, especially robotics projects etc, at home! Before you get started try to project how much your project may cost.
- **Feasible!** Make sure you come up with a project you can actually do! This means work on a project on your level of understanding, and that you can really put the time into doing!

1 "Intel International Science and Engineering Fair." *Intel*. Society For Science and the Public, n.d. Web. 09 Jan. 2014. <http://www.intel.com/content/www/us/en/education/competitions/international-science-and-engineering-fair.html>

Finding the Right Lab

There are many different types of research labs that require different levels of commitment and communication. Try to find one that connects with your interests and might be able to provide material and mentoring for the type of experiment you want to conduct.

Here are just a few

- Chemistry
 - Consists of organic chemistry, inorganic chemistry, physical chemistry and analytical chemistry.
 - Typical chemistry labs will require high levels of commitment and communication with your lab and mentor. Often, a good high school chemistry project is the product of working 20-30 hours/week during a summer (3 months) and 10 hours/week during the school year (around 5 months) before the date of science fair.
- Biosciences
 - Includes categories such as microbiology, biomedicine, biotechnology, and environmental research
 - A bioscience lab is similar to a chemistry lab in terms of commitment and communication with your lab and mentor. A good high school bioscience project is the product of working 20-30 hours/week during a summer (3 months) and 10 hours/week during the school year (around 5 months) before the date of the fair.
- Physical sciences
 - Includes physics, computer science, geophysical science, and statistics
 - Physical science labs are less intensive about time schedules and direct communication with your mentor. It still requires lots of time and analysis, but much of it can be done at home with a computer. The lab usually provides previous data on an experiment and software for analysis.

Rules

Intel ISEF has many rules regarding what students are allowed to handle in their experiments.

The official rules for 2014 ISEF can be found here:

<http://member.societyforscience.org/document.doc?id=398>

A few of the most important ones are listed below:

- Experiments involving human participants require preapproval from an Institutional Review Board (IRB) and informed consent from the research participant, with few exceptions.
- The use of vertebrate animals is allowed. Students must satisfy local, state, country laws and regulations of the jurisdiction in which research is performed as well as U.S. federal

law. The projects must not cause more than momentary or slight pain or distress to the animals, and no animal death due to experimental procedure is permitted.

- There must be detailed and safe procedures for handling potentially hazardous biological agents, especially in projects involving microorganisms (including bacteria, viruses, viroids, prions, fungi, and parasites), recombinant DNA (rDNA) technologies or human or animal fresh/frozen tissues, blood, or body fluids

It is imperative to follow all of these rules, otherwise your project can be disqualified from competition.

Finding a Lab

Now that you have an idea of what type of lab you want, the next step is to try to find one that will accept a high school intern. There are several ways of getting in contact with a lab.

- Personal connection
 - If you have a relative or friend working in a lab, ask if they can help you get an internship with their lab.
 - I was lucky enough to enter a lab with my mother as my mentor. It was great because I was in her company more than most students are in the companies of their mentors, thus I was able to learn more from her in a shorter period of time. On the other hand, it was difficult having my mother also as my teacher. The relationship was occasionally less professional than it could have been, and led to a few conflicts. A too-familiar mentor could take away from the intern and science experience, and a more distant relative or friend could be a better choice.
- Mentorship programs
 - The Science Fair has programs in place to help you find a mentor. Many students have been able to find mentors through emails between the students, interested mentors, and the science fair as a trusted intermediary.
 - A new program this year includes a mentor-meeting day during which students have the opportunity to meet scientists, technologists, engineers, and mathematicians to discuss science fair projects and match up to a mentor.
- Summer Research Programs
 - The Bioscience Summer Research Program for high school students at the University of Utah is offered to students in 11th grade and occurs during the summer after 11th grade. More information at <http://www.biology.utah.edu/undergraduate/research/hsprog.php> The students admitted will receive:
 - A two-week intensive laboratory techniques course that meets daily.
 - A six-week individual research experience on campus, with a University faculty member serving as the research mentor.

- Potential research topics that span the broad spectrum of the biological sciences -- from ecology to biochemistry.
- A \$500 stipend.

Background Research:

1. How to conduct background research
 - a. Use credible sources: Trust the Experts!
 - i. Science is based on repeated trials and experiments showing consistent and significant results. Therefore, it is very important to use papers of those who have tested their experiments greatly. Scholarly papers are a crucial source to cite as they generally are thoroughly done evaluations on that particular field of research. Utilizing search engines like Google Scholar and finding those credible papers on the research will greatly increase your understanding, but also the credibility of your own research
 - b. Wikipedia: Learn the Basics
 - i. Wikipedia is a difficult source to use because it is written by people who may not necessarily be experts in their particular field. Therefore, it is not a very good source to include within the research. However, Wikipedia is not a bad source of information. It is actually very helpful in building knowledge and a basic level of understanding.
 - c. Search Engines: Search it up!
 - i. Search engines are great methods of narrowing down the search. Things like Google Search can effectively try and find information on your research topic
 - d. Professor: Ask Around!
 - i. If a research paper is found that is not completely clear, it is also an option to communicate with the authors of the paper. While this may appear to be a daunting task, it is relatively easy to communicate with the authors and ask any questions that you may have.
2. What to include
 - a. Research: Cover all the Fields!
 - i. Include all information that is pertinent to your particular research project. In particular, make sure to include the proper terminology and make sure to define each of the terms. Each aspect of the project should be carefully explained to make sure that the reader knows the applicability of the experiment. Things like materials should also be included. Finally, the current systems in place and the problems that the current system has needs to be addressed. Therefore, the reader can understand why the research actually matters.

3. Formatting

- a. APA Citation: Use APA!
 - i. There need to be in-text citations and a bibliography in the standardized APA format. Using an online source can help with proper citations.
- b. Terminology: Define All the Terms!
 - i. Be sure to define all the terms. Not all terminology is necessarily well known. Make sure that for every term if you had to look it up or learned it in class then include it in your journal.
- c. Gross Equations/Formulas: Do the Math!
 - i. Include all formulas and calculations such that the readers are able to fully understand what processes are done. The actual calculations should be done following the methods listed in the research paper.

Research Plan

For nearly every project, especially senior division projects, a research plan is required. For senior division project, it is necessary to create a research plan as it is a required part of ISEF forms. A research plan is of the utmost importance if you want to do an independent project within a research institution or a lab, as many lab directors or professors want to see what materials you need, your procedure, and a general idea of your project. Below is a general idea of how one should format a research plan:

- **Introduction:** Present an introduction to the project. Include some general information, what some people have done in the past, and how your research relates. If your project is an improvement upon previous research, explain why your research is better or possible improvements to previous research. Introductions need to include what is known about the topic and what is unknown, and will ultimately lead to the question that you are proposing to answer.
- **Research Questions:** The question should be aimed to what you want to find out in your project. A lot of the time, research questions are meant to be used as guiding questions; however, at times a WHY question is a very hard question to even remotely try to answer. An example of a research question is listed below.
 - E.g. Do different concentrations of TiO₂ and ZnO affect daphnia magna survival rate and heartbeat differently?
- **Hypothesis:** The hypothesis (or hypotheses) is related to your research questions, and will be based on the knowns and unknowns described in your Introduction. It helps to further structure your project and gives more specific guidance to what your aim is, as well as your prediction to what may occur within your research. The hypothesis needs to be tentative; suggesting that 2 things “may” be related (your independent and dependent variables). It needs to be testable and possible for you to perform the research/experimentation (academically, physically, and

financially). A hypothesis generally includes a prediction of what you may find, but the prediction can only be included after background research has been identified (the “knowns”) and the relationship you will be testing has been stated.

- A hypothesis can be in an “if then” format, but there are other ways to format a hypothesis. Below are some examples of formatting hypotheses:
 - E.g. Acid concentration and volume would affect the metal ion recovery using a preconcentration method for heavy metal analysis in water.
 - E.g. The nano sized TiO_2 and ZnO are more toxic than the bulk sized TiO_2 and ZnO .
 - E.g. If the intensity of the light increases, then the rate of photosynthesis will also increase.
- **Experimental Materials:** For the experimental materials, include ALL materials used, including major and minor ones. Also for all materials include the company that the materials were bought from.
 - So if you had 5M of nitric acid from Sigma Aldrich, then the materials list would read, 5M nitric acid (Sigma Aldrich).
 - **Experimental Procedure:** This section can be used describe what materials will be used in a procedure format. However, the main focus of the section should be on the procedure that will be used for experimentation. The experimentation will be described in a very basic format, where it will involve an idea of experimentation performed, but the procedure should be done with little analytics and it should be done in a way that is fairly simple.
 - **Data Analysis:** The data analysis should be done in a way that it is a brief description, but if there is a more intensive section of calculation or analysis then, include a basic idea of it.
 - **Bibliography:** For any references used within the journal, cite them in APA citation and place them in the research plan.

Experimental Procedure

There are generally three different types of projects: experimental, analytical, and engineering. Each has a different procedure.

- Experimental projects follow the scientific method
 - Ask a Question
 - Do Background Research
 - Construct a Hypothesis
 - Test Your Hypothesis by Doing an Experiment
 - Analyze Your Data and Draw a Conclusion
 - Communicate Your Results

- An analytical project uses data from experiments or studies that have already been conducted. It can thus skip the experimental step in the scientific method and put the focus on methods and results of analysis
 - Ask a Question
 - Do Background Research
 - Gather Data from Other Sources
 - Analyze Your Data
 - Draw a Conclusion
 - Communicate Your Results
- Engineering projects are very different. The general method is as follows
 - Define the Problem
 - Do Background Research
 - Specify Requirements
 - Brainstorm Solutions
 - Choose the Best Solution
 - Do Development Work
 - Build a Prototype
 - Test and Redesign

For all projects there some details must always be included. These details include that for each step if it involves making or adding solutions be sure to include specific concentrations/volumes of certain materials. Also it is always a good idea to take multiple areas and divide using headers/bullets.

Notebook

1. **Keep a notebook:** Take Note!
 - On every day you conduct a trial or do something related to the experiment, make sure to take a tab as to what you've done that particular date. Dates should be included to make sure that the experimentation is accurately recorded. Make sure to give enough information on each date, so the reader can understand the timing and results of the experimentation.
2. **What to record:** Keep the Record!
 - Make sure to record all of the information that is pertinent to the experiment. In particular, record the qualitative and quantitative information that are directly related to the experiment. Also, include any unique observations in the actual experiment. Information like bubbles forming is very important, so don't be afraid to record all observations. If anything in the procedure or trials has been altered, make sure to report these such that any discrepancies aren't found.

Data Collection/ Data Analysis

When collecting data, there are a few things we must take into account. First, what were the

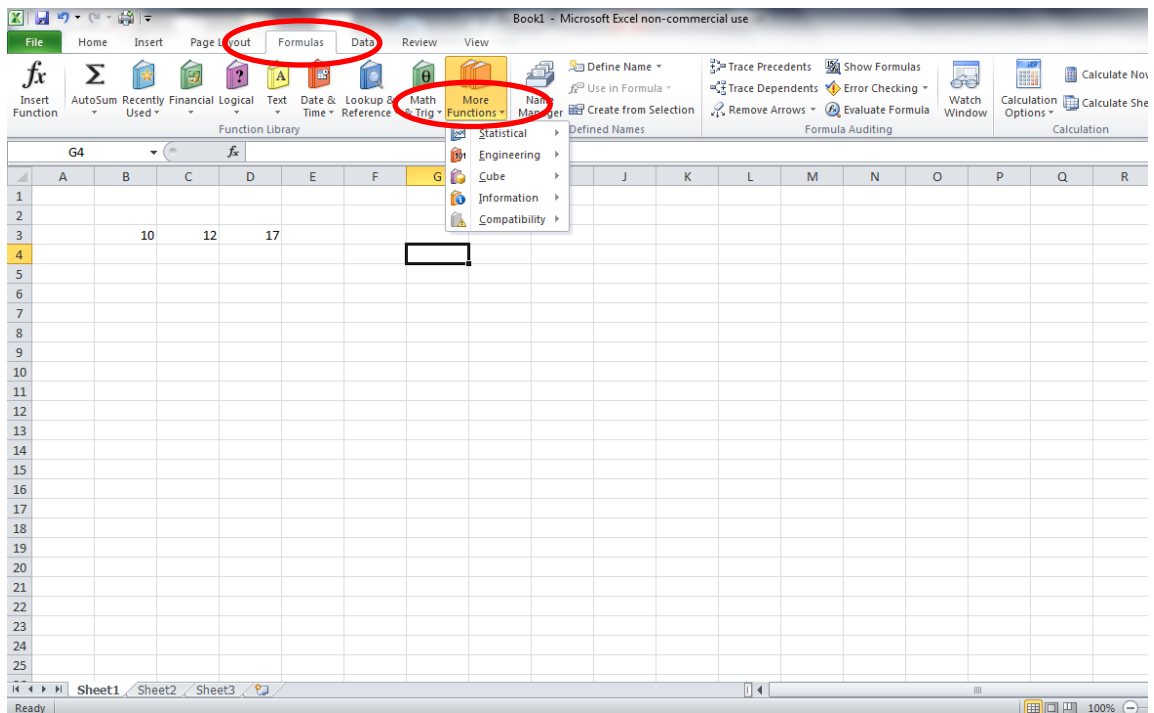
independent, dependent, and control variables? As a review, allow me to explain each of these things.

- Independent: What you are changing in your experiment. (Light intensity, concentration)
- Dependent: What you are measuring as a result of your independent variable. (plant growth, rate of reaction)
- Control: What are you comparing all of your results to? This can be anything from the maximum magnitude of your independent variable to the minimum amount. For example, if I was testing Light intensity, then my control may be zero light; whereas if I was testing concentration, then my control may be 100%.

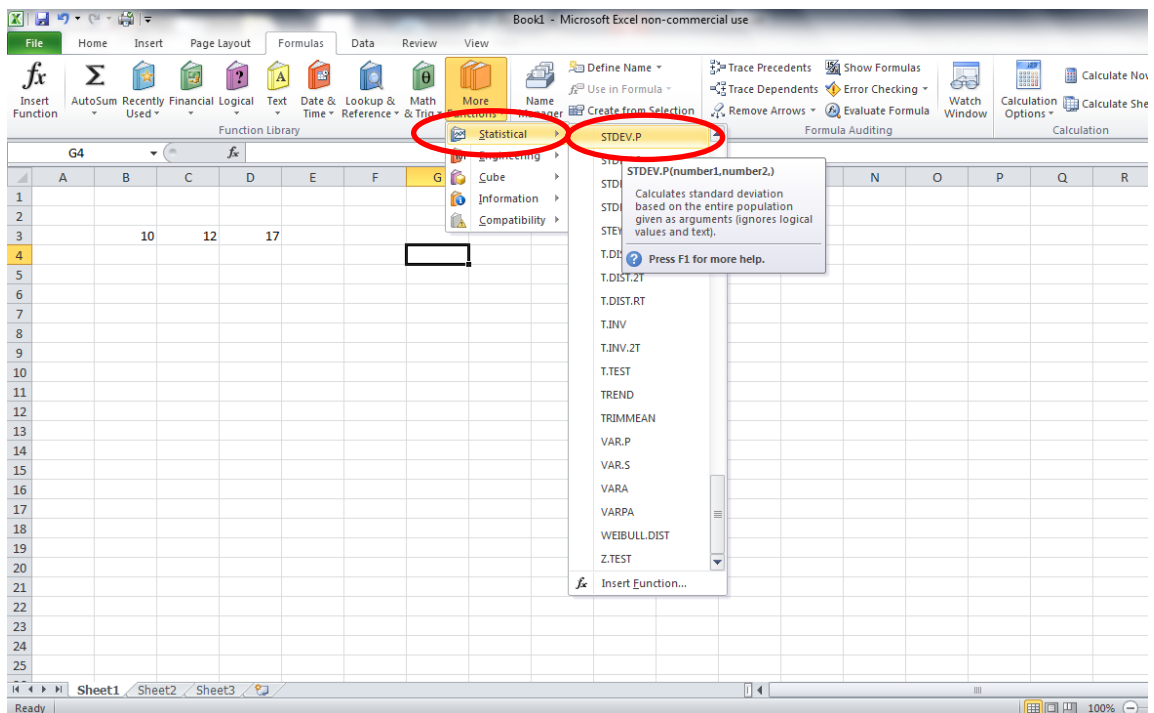
Now that we have gone over the necessary components, let's delve into the fun part: the data collection. First of all, it is important to collect your data in your journal or on a computer so that you do not lose it. It is also important that you set certain intervals to collect data. For example, I will check plant height 3 times per day. But, I have to be more specific. I will check it 3 times per day, first at 10 AM, then at 3PM, then at 8 PM. Notice that all intervals have a difference of 5 hours and are done during the waking hours of the day. Next, it is important to collect data for a long enough time such that significant data may be collected. For example, if I were to collect data for plant growth, I would do it over a period of a month. But, if I were testing an enzyme's rate of reaction, then I would collect data for approximately 1 to 2 minutes. In addition, it is imperative that you know what the units are for your data collecting. I would not want to measure plant growth in miles, nor would I want to measure a rate of reaction in years, because both units would yield miniscule numbers that would be extremely difficult to analyze later on. Consequently, it is also important that you use the same amount of units for all measurements. This is done so that the accuracy of your data can be maintained and because of presentation purposes. It is very unprofessional in the field of science to have one data point read 3.7 and another read 3.765. Even if your experiment does yield a data point of 3.7, it should be written as 3.700. Finally, it is important to gather enough data points. It is recommended that you test 3 magnitudes of your independent variable (for example, if I were testing concentration, then I may test 25%, 50%, and 75%) and have at least 3 repetitions, commonly known in the field of science as trials, for each independent variable (for example, I would repeat my enzymatic reaction in a 25% concentration 3 times). This provides more lines of evidence for you to complete your data analysis.

Data Analysis is the component of your science fair project that leads into the conclusion. One cannot have a sound conclusion unless they analyze their data in multiple aspects. Most often, data analysis involves taking averages and doing statistical analysis. The most important aspects of data analysis are taking the average (mean) of a set of data and calculating standard deviation. Let's start with taking the average. This part of data analysis is very important because it takes into account all of your repetitions (trials) for each magnitude of independent variable and allows you to come up with one, representative data point. For example, let's say that when

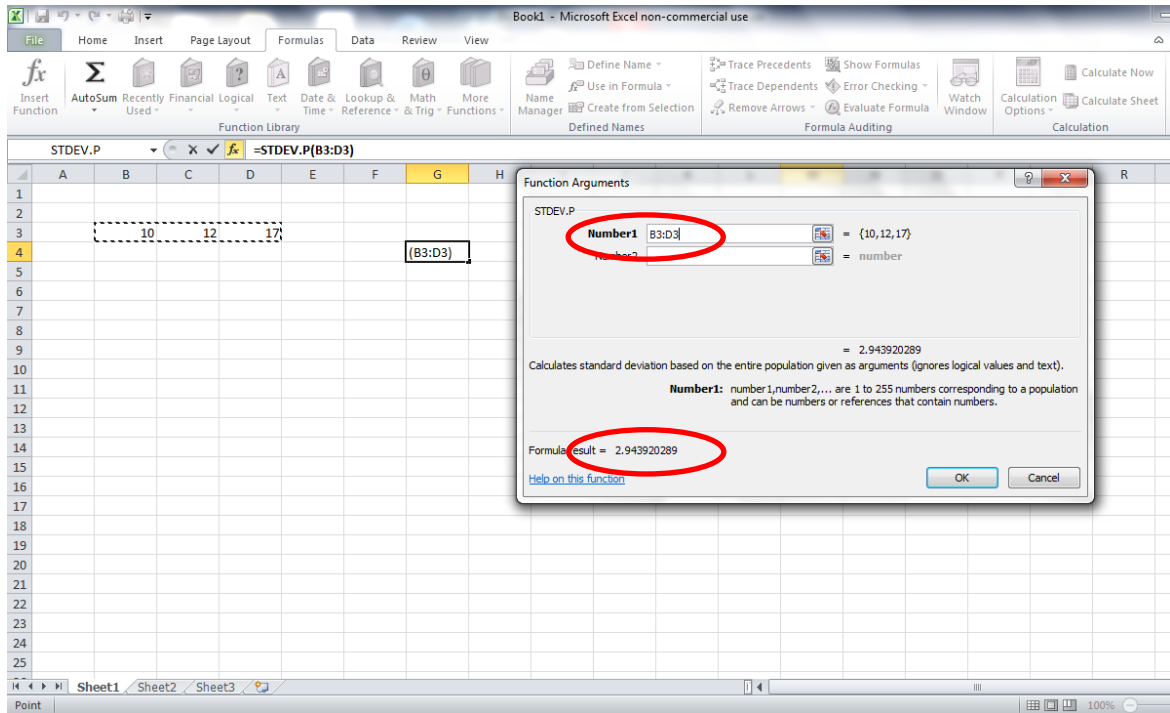
2. Select the “Formulas” tab located towards the top of the page and click on the “More Functions” dropdown menu.



3. Choose the “Statistical” dropdown menu, scroll down to STDEV.P, and click on it.



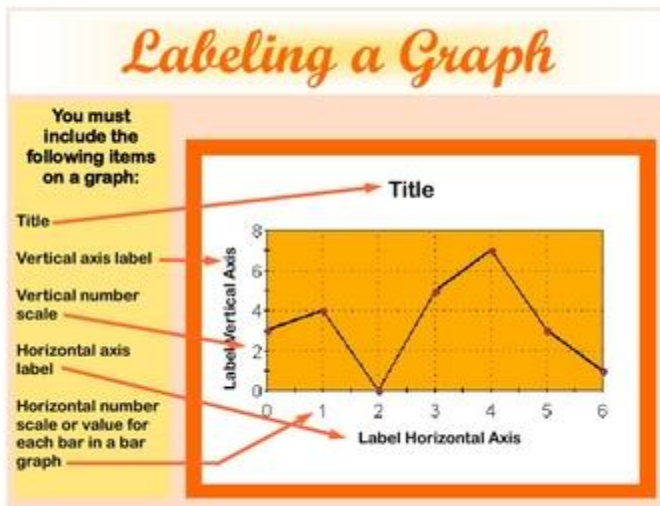
4. Select which cells you want the Standard Deviation to be calculated on. They can simply be typed in. After you have done this, the value of the Standard Deviation should come up at the bottom of the text box.



And Voila! Once you have both the average values and Standard Deviation Values, you can begin graphing. Graphing can also be done on Microsoft excel. Here are some important things to remember about graphing.

1. Every graph needs a title!
2. The “Y” axis should be labeled with the dependent variable.
3. The “X” axis should be labeled with the independent variable.
4. Choose appropriate graphing intervals, you do not want your data to only take up ¼ of your graphing space.
5. If possible, include standard deviations.

Here is a picture to aid you:



By now, you should have collected enough data and done a sufficient amount of data analysis so that you can draw conclusions about your experiments!

Conclusion:

What is a conclusion? A conclusion is essentially a summary of your results. It is basically the “so what?” of the experiment, meaning that it ties together the results obtained from the experiment and the purpose of the experiment. A conclusion should be written in such a way that a spectator could read it and get a basic idea of what the experiment was testing and what the results were. A conclusion should typically be about a ½ page.

How do you write a conclusion?

A well-written conclusion should include the following:

- An exact answer to the purpose.
- Bits and pieces of the data collected during experimentation that reinforce the answer to the purpose.
- Some observations recorded throughout the experimentation.
- Possible reasons as to why the results came what they were.
- Was your hypothesis correct or incorrect?

Here is a general template for a well-written conclusion (the order in which you present the items listed above is not too critical, but the conclusion must have a good flow):

“The results obtained from this experiment show that (answer the question stated in the purpose). This is because (include some data to support the results). A possible explanation for this is (insert why you think the results came what they were). I observed throughout the

experiment that (insert any important observations you made throughout the experiment). My hypothesis was (supported/unsupported) by the results of this experiment.”

Evaluation:

An evaluation is essentially the “now what?” of the experiment, meaning now that you have an answer to your purpose, what will you do with that?

Although the evaluation of a science fair is not required (as it is not a part of the scientific process), it generally distinguishes a student from the others. While writing the evaluation, you have to really think about why the results you got are relevant.

When a judge interviews you at a science fair competition and sees that you know how to apply your project and findings to the real world, he/she will be quite impressed. The judge will see that you took the time to analyze and see the importance your experiment may have in the real world. Your chances of winning will significantly increase if you include an evaluation for your experiment.

How do you write an evaluation?

A well-written evaluation should include the following:

- An application of the experiment to the real world.
- The impact that your results can have on the real world.
- Future research you would conduct/ what would you do if you were to continue your experiment.

Here is a template for a well-written evaluation:

“My project is very well related to the real world. The results of this experiment show that (insert a general summary of your results, along with a portion of your conclusion). This conclusion applies to the real world because (insert a THOROUGH explanation of why/how your conclusion relates to the real world). The results of this experiment are very promising because (explain how the results of your experiment may help the real world situation).

If I were to further continue my experiment, I would (insert what you would do in the future).”

A well-written evaluation should typically be about a ½ - ¾ page or 2-3 paragraphs.

Bibliography:

A bibliography is simply a list of all the sources you used for help in conducting your research. Including a bibliography is a step that many participants overlook. They feel that

including sources is not essential. In actuality, you may get disqualified for not including your sources since it is a violation of the rules to use somebody else's work and not give them credit for it.

Writing up a bibliography is not too difficult unless you make it difficult. In order to avoid creating a bibliography at the last second, you should record all websites you use WHILE conducting research.

There are many websites that can help you correctly cite your sources. Here is a list of websites that I have found extremely helpful over the years:

- Citationmachine.net: this website allows you to choose which type of formatting you would like to use (such as MLA, APA, Turabian, etc.). The website has a built-in template for correctly citing sources; all you need to do is enter the necessary information.
- Easybib.com: this website is also similar to the one above, but only allows MLA for free. The prices for citing in APA or Chicago/Turabian are not too costly, though.

Journal Formatting

For the journal it just needs to be in a logical comprehensible order. This means that there actually is a lot of logic to the chaos. Virtually it should also be in an essay but, take a more scientific standpoint. What this means is that in the journal, everything should almost come in the order that you format it. So it would be logical to put background research before the hypothesis, as background research is needed for even creating a hypothesis.

- Table of Contents: this should first of all include page numbers of the big headers, so research questions, background research, variables, materials, procedure, data analysis, conclusion and evaluation, and bibliography. However, the next part is also important which, includes a list of tables and a list of figures.
- Page Numbers: this might seem simple, but you have to remember for the figures and table numbers, it becomes a lot harder, as the figures and tables can be shifted farther back into the journal. Just be careful when formatting page numbers.
- Tables and Figures: So first of all for tables and figures, use full page tables and figures since, this is journal, there is no space limit. The full pages allow for judges to better understand the project if necessary.
- Images: so for images there are usually two acceptable places to put them in the journal. The first way is if it a diagram of your project and it is almost imperative for its understanding feel free to include it in the main text. This allows for everyone including you to understand in context the procedure used at times. However, other times there are images such as you yourself doing the project.

This typically would go in a section that would be labeled appendix. The appendix is used for all extra images of the project.

Making your science fair board:

The science fair board is how you present all your hard Science Fair work! There are several things you need to have on your board.

- **Project Title:** This is a fun way to summarize your project and catch attention. Have fun with it!
- **Abstract:** Abstracts are not the same as summaries. Basically it is a compilation of one sentence from each of the rest of your sections. Instructions for how to write one: <https://owl.english.purdue.edu/owl/resource/656/1/>
- **Question and Hypothesis.**
- **Materials:** a recipe list for everything you used in your project. From the journal portion this is first formatted in a manner so it is shorter than the journal and more compact.
- **Procedure:** think of this as a way to instruct other people on how to do your project. Write very detailed instructions. This should not be as detailed as the journal, but it should be detailed enough for a judge to understand your project while reading the board.
- **Results:** Include many graphs and tables. Excel can be an excellent way to present you data! This is a basic description of how to make various graphs etc. using excel: <http://www.ncsu.edu/labwrite/res/gt/graph tut-home.html>, while if you want to make a chart, this will be useful: <http://office.microsoft.com/en-us/excel-help/create-a-chart-HP001233728.aspx>
- You can ask for help making graphs and presenting data if you need to!
- **Conclusion:** This is the section where you analyze the results of your experiment. Did your results support you hypothesized? Why or why not? What are the possible implications of your results? How can you save the world? Etc.
- **Bibliography:** It is essential that you include citations for all work that is not your own. Easy Bib is a convenient resource for helping you cite: <http://www.easybib.com/> And for questions about formatting visit the Purdue Owl: <https://owl.english.purdue.edu/owl/resource/747/01/>

Other things you may want to include:

- Photos of your project and experimental setup.
- Additional thing you could do on your project for the future.
- Art to decorate your project!
- Research Background: A quick summary of the research you did for your project. Make sure to cite everything you have learned!

Make sure to check with your local science fair for their rules and restrictions for what you can have on your project or on display. Below are some of the common limitations:

- Water
- Glassware
- Photos of yourself or other people (make sure to include citations)
- Sharp, dangerous, or explosive objects

There are also restrictions on how big your project can be:

It is suggested you use the ISEF guidelines which are:

- **Depth** (front to back): 30 inches or 76 centimeters
- **Width** (side to side): 48 inches or 122 centimeters
- **Height** (floor to top): 108 inches or 274 centimeters

The complete list of guidelines and regulations can be found at:

<https://student.societyforscience.org/intel-isef-display-and-safety-regulations>

Tri-fold Project boards can be purchased at you local grocery store. It is also possible to purchase larger boards and to build your own. Just ensure you project board meets the guidelines above.

Judging

Judging can both be nerve racking and also extremely exciting. At SLVSEF, judging for elementary school students starts on 10 a.m. to 2 p.m., while junior and senior division judging takes place from 9 a.m. to 2 p.m. For this time typically you stay at your booth. When judges start to come first they either start to ask questions immediately, if they already have questions, and some will let you present then, ask questions. This time is important to show what you have done over the past period of time in your research! Enjoy this time, it is an amazing time to share your research with a multitude of brilliant scientists.

Past Experiences

Summer Research Programs: Bioscience Summer Research Program

I attended this program last summer and gained so much from it. The 2-week training course helped me learn the basic techniques commonly used in most bioscience research laboratories. Although I had knowledge of a few techniques that I used frequently at a previous lab, such as pipetting and PCR, this course introduced me to a few other basic techniques that I had no experience with before, including protein extraction from tissue. At the end of those 2 weeks, I chose to work at a biochemistry laboratory that was more intensive than most of the other labs in the program (based on what I heard from my friends). I was glad that I had chosen this lab, despite its great time commitment, because I learned so much about the actual frantic life of a scientist and I was able to become familiar with many methods such as sequence- and ligation-independent cloning (SLIC), culturing bacteria, and purifying proteins.

Background Research

Bovey Rao: I always take my time to do the research sufficiently such that not only do I have an understanding, but any reader is capable of understanding why my project really matters. I wanted to make my experiment of producing biofuels from grass clippings as important as possible.

Notebook

Bovey Rao: Make sure to take notes of every day that the experiments occurred. If you forget, make sure to record it on the correct dates or else things can get hectic. I can attest to losing track of exactly where I was.

Materials List

For the materials list, errors are sometimes included depending on the person and the preference; personally I have never done this in a science fair project.

Research plan to Journal Formatting

What I have found useful is taking the research plan and then expanding upon it to form the scientific journal/paper for the year.

Table of Contents

Personally for the table of contents, I follow this format just so it makes things really easy to find. Since, I had over 50 tables and figures together for my project, it was a big mess, but this helped create some organization.

Abstract on Board:

Many people choose to place their abstracts on their boards. However, this is not necessary, but if you wish to place it on your board, feel free!