MathScience Innovation Center

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Metro Richmond STEM Fair

Beginner's Guide

How to Develop a Great STEM Fair Research Project and Paper for the Metro Richmond STEM Fair

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Lab Notebook

It all starts with a Lab Notebook. A lab notebook is an important part of beginning any research or engineering project. You can decide if you would rather use a physical notebook, record your notes using Google Docs or a similar virtual platform. Either way, when used properly, your lab notebook will serve as a permanent account of every step of your project — from the initial brainstorming to the final data analysis and research report. Keep in mind that it is imperative to have a draft of your literature review and procedure before you begin your experiment — so keep good notes in your lab notebook.

Documentation from your lab notebook must be presented at the Metro Richmond STEM Fair, so be sure to get in the habit of using it whenever you do something involving your research. If you have chosen to use Google Docs, you must print out a copy of your documents to have on hand at the fair.

Organizational Methods

One organizational method is to number your pages and create a Table of Contents, so that you may find information quickly and easily during your project. Also, it is helpful if you divide your lab notebook or Google Docs into sections or folders. The sections or folders should include:

- project/topic ideas
- research that helped you narrow your topic
- your research plan
- materials list
- the steps of your experiment or procedure
- data collection (ex. graphs and tables);
- other observations you make during your experiment or procedures
- data analysis
- conclusion and results

Selecting a Topic

The first step in conducting a research project is to decide what to investigate. It is helpful to brainstorm your ideas. Give yourself time to reflect on your interests and to think about the questions that have always puzzled you (e.g. What would happen if…? I wonder why…?). Use your lab notebook to record your ideas. Start with a broad topic/idea and then begin to narrow it down. The following are websites that may spark your interest: http://Sciencebuddies.com and http://Livescience.com.

Narrow the Topic

Ideally, you want to find the answer to a question that has been previously ***unasked***. Your research should set out to answer a question that will help you better understand the world around us. When you are thinking about your topic, it is also important to identify how your project links to various scientific concepts (i.e. What is the science concept behind your idea?).

For example: Physics principles are behind much of engineering. Why will one bridge design support more weight than another design? If you are designing something, you need to know how it works and what makes it work in a particular way. Then you can build a model, test, and re-design it to make it more efficient and structurally sound.

Keep in mind that there are a few topics you should avoid:

- Projects in which the goal is to determine a simple preference or taste. These projects do not involve the kinds of quantitative (numerical) measurements that will result in a competitive science fair project. These types of projects are more of a survey than an experiment. Examples include: consumer product testing which may compare types of food, bubblegum, makeup, batteries, cleaning products, paper towels, etc.;
- Overdone or obvious topics like the:
    - effect of colored light on plants. Several people do this project at almost every science fair. You can be more creative!;
    - effect of exercise, music, video games, or almost anything on blood pressure or heart rate. The result is either obvious (the heart beats faster when you run) or difficult to measure without proper controls (the effect of music).
- Any topic that requires dangerous, hard to find, expensive, or illegal materials;
- Any topic that requires drugging, pain, or injury to a live vertebrate animal;
- Any topic that creates unacceptable risk (physical or psychological) to a human subject. (http://sarsef.org/students/high-school/step-by-step/); or
- Any topic that requires difficult measurements beyond your expertise.

Talk with your teacher about your project idea before moving forward. Your teacher will be able to determine if you have sufficiently narrowed your topic. Additionally, your teacher will be able to provide suggestions about how you might proceed with your work, if necessary.

Also, be sure to talk with your family (and teacher) to think through the following:

- Where will you perform your experiment?
- What materials and technology will be used and how will you gain access to these resources?
- How much time do you anticipate spending on the project and when will you be able to work on it?
- What mathematics or statistical principles will need to be used in your project? If needed, who will support you in doing these mathematical/statistical measurements?

Restricted Project Information
Be sure to check to see if your topic is considered to be restricted, as there are additional requirements for these types of projects that need to be completed **before** you begin your research (e.g. working with *E.coli*, tissue, hazardous chemicals, etc.). Restricted projects must adhere to the instructions found on the Intel ISEF website under the Rules and Guidelines / Forms.

Background Research
At this point you should review the literature to gather as much background information on your topic as possible. Pay attention to what the prevailing thoughts are on your topic and if there is a widespread consensus or dissension among scientists and researchers. Be sure to include a brief synopsis of important ideas in your lab notebook. By reading widely on your topic, you will develop an awesome research question.

The most practical way to begin a review of literature is to read current studies and journal articles from the original research. This will familiarize you with what other researchers have already explored around your topic of interest. If you can, find articles that examine and summarize the results of many publications. Talking to experts in the field will also provide valuable information about research that has been previously done and will help you to uncover new questions to pursue or help you to refine your research question and hypothesis. Your librarian may be an excellent resource for you, as well.

Now that you have chosen and narrowed your topic and completed your literature review, you should refine your research question and hypothesis.

Developing a Rationale
The rationale should be written to explain why your research is scientifically important. What is your practical reason for conducting the experiment (i.e. **Why** was this topic chosen? **How** will it benefit society?)? To help the reader understand the rationale, it is necessary to provide some background information on the variables being investigated or to describe other studies conducted by scientists. The purpose should be written to express what you hope to achieve or learn.

Developing a Research Question and Hypothesis
Your research question guides your work. Research questions usually start with: How, What, When, Why, or Where (i.e. What happens when…?). When designing a research question, keep in mind that it needs to be clear, concise, and do-able (i.e. Can you design a project that could help you answer your question?). Also, it may be helpful to think about what you might find when you conduct your research based on what you have learned from your literature review. The hypothesis should be written in the "if...then" format in your lab notebook to document your prediction of what you think that the results should be.

At this point, you should begin to fill out the following forms: Form 1A, Form 1 and Form 1B. Note: Since you have not completed your experiment/data collection yet, the start and end date of the experiment/data collection should **not** be filled in on the

Student Checklist (1A).

Writing Your Procedure

Your procedure should be a detailed account of how you plan to carry out your project/experiment. Remember, good scientific experiments only have one variable and all the other conditions are kept the same. The following link may be helpful to you:

http://www.longwood.edu/cleanva/images/sec6.designexperiment.pdf

Remember, as scientists we are allowed to collaborate and build on the ideas of other researchers. However, the procedure that you write must be different than anything that has already been published.

Risk and Safety

Adhering to safety rules and protocols is of paramount importance for every scientific experiment. Even though most projects pose no risk, a tool or technique deemed "safe" could become extremely dangerous if misused. It is imperative that you document any risk and or safety concerns within your research paper as well as on Forms 1 and 1A. These forms are great tools to use when assessing the risk of your science project and the safety precautions with which you need to adhere to and ensure that:

- people and animals involved in your project are safe;
- your project is based on the safety regulations of Intel ISEF;
- all relevant parties have appropriately assessed the risks associated with your project and that safety precautions are planned for and carried out.

Prepare for Data Collection

Prepare data tables in your lab notebook to help organize your raw data in preparation for data collection. A data table will ensure that you are consistent in recording both your raw and processed data and will make it easier to graph and analyze your results once you have finished your experiment. It is a good idea to think about how you will summarize your data. One way of doing this is to prepare graphs ahead of time to aid you in thinking about how you will efficiently communicate the data that will be collected.

Bibliography

It is essential that you cite ***ALL*** of the books, magazines, and websites that you utilize in your research paper. This list of sources will become your bibliography. There are many websites that help in citing sources; one such site is the Citation Machine. These should be written using an acceptable style manual such as the American Psychological Association, The Chicago Manual of Style, or those of the Modern Language Association.

Although there is no magic number in terms of the number of sources that are used in the bibliography, it is common practice to have at **least 5 major sources,** such as books, journals, periodicals, etc., cited in the text of your paper.

Plagiarism is a serious offense, as it is stealing. Citing your sources is a quite simple way to give credit to its author, thereby being able to legally use his/her content.

Gather Your Materials & Set Up Your Equipment

What type of supplies and equipment will you need to complete your science fair project? By making a complete list ahead of time, you can make sure that you have everything on hand when you need it. Some items may take time to obtain, so making a materials list in advance is particularly important in that you have a limited time to complete your project.

The next step is to gather the materials, supplies and equipment needed. Make sure that you have the necessary safety equipment (e.g. gloves, protective eye wear, a hair tie to pull back long hair, fire extinguisher, etc.).

Avoid a Vague Materials List	Make a Specific Materials List
water	500 ml of deionized water
clock	stopwatch with 0.1 accuracy
battery	AA alkaline battery

Once you have gathered your equipment, be sure that it is in working order and that you know how it operates. Taking pictures of your equipment setup is helpful when you are describing your work in your research paper and when talking to judges.

Perform Your Experiment and Collect Data

With your detailed experimental procedure in hand, you are ready to start your science experiment! Be sure that you use the same procedure/methodology each time you repeat your experiment so that your results will be accurate. Keep detailed records of exactly what you do, so that you, or someone else, can replicate your experiment. If possible, have someone take pictures while you engage in your experiment.

Get in the habit of starting a new entry in your lab notebook as soon as you begin working on your science project for the day, even if you are only taking a quick measurement or doing a visual check. Write down the date and then record what you do. Record your data in your data tables as you complete the trials of your experiment.

As you collect the data, look at it to determine if the data is reasonable and provides an answer for your research question. If your data seems “out of whack”, you might want to stop and re-evaluate your procedure. This is not necessarily the same as confirming your hypothesis — It could be that your original predictions are false and that is perfectly fine. The goal of science is to ***discover truth*** and it does not matter if it comes from a supported or disproven hypothesis. The scientific community wins either way!

Data Analysis

When you begin data analysis, you will have data from multiple trials of your experiment. You usually need to perform calculations to generate a conclusion about the data. Graphing your data may help you see trends. A spreadsheet program such as Microsoft Excel may be a good way to organize your data.

Think about the best way to summarize your data. For example, do you want to calculate the average for each group of trials or summarize the results in some other way? Will you summarize the results as ratios, percentages, or error and significance? You may want to ask for help when deciding which (if any) statistical tests are needed. Make sure that you **understand** each type of test before you include it in your research paper. It is more important to have relevant, simple statistics rather than complex statistics that are not in alignment with your study.

Simple statistics, such as mean or median, are appropriate for middle school students. For older students, a statistical test should be used to determine if the results are statistically significant. The simplest types of statistical tests are the t-Test, to determine if there is a significant difference between the means, and the Chi-Square is used to determine if there is a significant difference between frequency distributions.

For information on statistics, see a middle school mathematics textbook, a senior high or college statistics textbook, or Students & Research (ISBN 978-0-7575-1916-1). Also, the following website may help you determine which tests you may need.
http://www.ats.ucla.edu/stat/stata/whatstat/whatstat.htm

Once your data analysis is complete, you are ready to write your paper.

Displaying Your Data

Graphing data is an excellent way to not only see trends but to communicate your results. The type of graph you choose depends on several variables. You can draw many different graphs in your lab notebook (or paste them from a printed spreadsheet) and see which one(s) work(s) for your data. The graph or graphs you choose for your report should show your results clearly.

Tips for graphing:

- Choose a graph that shows your results clearly. Choices include:
    - **Bar graph** – used to compare groups or traits between groups. A good choice if you have categorical data (like: green, red, blue) and usually shows frequency (how often something happens).
    - **Circle or pie graph** – used to compare a part to the whole. A good choice for data at a point in time. This graph is not a good choice for showing change over time.
    - **Line graph** – used to compare two variables. Typically, the X-axis is time and the graph can track changes over time (called a time series graph). This type of graph can also be used to compare changes over the same time between two groups.
    - **Scatterplot** – used to compare two variables. This type of graph,

sometimes called an X-Y Plot, is often used to show relationships between variables (e.g. both increase, both decrease). The X-axis (bottom) represents the independent variable, while the Y-axis (side) represents the dependent or responding variable.
    - **Box-and-Whiskers Plot** – used to display groups of data (numbers). This type of graph is used to compare how data in one group is distributed (spread out) compared to data in another group. Data is divided into quartiles with the middle quartiles represented in a rectangle (or box) and the outside quartiles are lines (or whiskers).
- Each component of your graph should be labelled clearly (e.g. axis, title, and source).
- Choose a graph that fits your data type. Depending on the type of data you have collected, you may be limited in your choice of graphs.
- Show your graph to someone that has not seen your data; ask them if they can read it. If they are confused or do not understand your graph, you may need to change how your graph looks. Remember, make sure your graph is clear, well labelled, and easy to read.

Basic Rules for Graphing:

- Your independent variable should be placed on the X-axis of your graph and the dependent variable should be placed on the Y-axis.
- Be sure to label the axes of your graph — do not forget to include the units of measurement (grams, centimeters, liters, etc.) and they should all be on the same scale.
- If you have more than one set of data, show each series in a different color or symbol and include a legend with clear labels.

Ask your teacher if you are not sure of the best type of graph(s) to use to display your data. The following websites may be helpful in choosing the right graph:

- https://nces.ed.gov/nceskids/help/user_guide/graph/whentouse.asp
- http://flowingdata.com/2010/07/22/7-basic-rules-for-making-charts-and-graphs/

Writing Up Your Research Paper for Submission to the Metro Richmond STEM Fair.

Your research paper is designed to give the readers a concise and informative summary of your research project. This paper is a refinement and organization of all the information you have written at this point.

Format Requirements:

- Title at the top of the first page of the paper (do not use a separate title page)
- 1-inch margins and 12-point font
- Double spaced
- **No personal pronouns (ex. I and we)**

- Junior Division papers must be 6 pages or less; Senior Division papers must be 8 pages or less. This length requirement does not include the References/ Bibliography section, the student information or certification forms, or the appendix containing any pertinent tables or graphic materials.
- The Society for Science & the Public has details on their website https://societyforscience.org/.

Tip: You may want to bring a more complete version of your research paper with you if you are accepted to the Metro Richmond STEM Fair to give judges a more complete understanding of your research project.

Title

A good title should simply and accurately present your research and should mention the variables being studied. The title should be easy to understand. Long, complicated titles do not impress the judges. You can come up with a "catchy" title but remember that a shorter title is also easier to use when registering online, filling out forms and talking to judges.

Be sure to check with your teacher about his/her rules on creating a title for your project. Some teachers may require you to use a scientific title which describes the independent and dependent variables. ***It is imperative that the title on your paper matches the title used for registration.*** Screeners and judges notice when there are two completely different titles being used to describe the same research project.

Introduction

The introduction sets the stage for the entire science project by introducing the reader to the reasoning behind the project. Capture the interest of the reader and give readers a preview of what they can expect in your paper. The introduction must include the following items (previously completed in your Research Plan):

- Research question – Be sure to state your research question and explain why we should care about the answer.
- Literature Review
  - Include a brief synopsis on how the literature relates to your research question using your notes from your Background Research. Also, you must situate your project in the context of what others have discovered and demonstrate an understanding of scholarship in this area. In other words, you must show that you are the “expert” on the section of literature pertaining to your topic and give a clear understanding on how your work fits into the existing body of knowledge.

Tip: It is important to draw the attention to what others have done in this field rather than writing a “laundry list” about your own project and ideas. It is not a good idea to use this section to show how much you have read. Rather, you must show that you have synthesized what you have read, draw connections to what others have said, show the outlying arguments, if there are any, and demonstrate your understanding for the current state of the field in which your research resides.

- http://www.monash.edu.au/lls/llonline/writing/science/lit-review/1.xml
- video: https://www.youtube.com/watch?v=Kwi2Dxk9wuY
- https://www.youtube.com/watch?v=2WSIkNJ1rJU

- Rationale
  - Explain why your research is scientifically important and what you expect to achieve or learn.
  - Describe the practical reason for conducting the experiment (i.e. **Why** was this topic chosen? **How** will it benefit society?).
  - Provide some background information on the variables being investigated or describe other studies conducted by scientists.

- Hypothesis
  - Think about the truth that you may discover when you conduct your research based on what you have learned from your literature review.
  - Write the hypothesis in the "if...then" format in your lab notebook to document your prediction of what you think that the results should be.
  - In the end, your original predictions may be disproven and that is perfectly fine. The goal of science is to ***discover truth*** and it does not matter if it comes from a supported or disproven hypothesis. The scientific community and the world at large win either way!

Procedures

The procedure should be written as a detailed account of how you plan to carry out your project/experiment. Remember, good scientific experiments only have one variable and all the other conditions are kept the same. Remember, scientists collaborate with one another to propel science; we build on the ideas of other researchers. However, the procedure that you write must be different from anything that has already been published. Reading numerous research papers on your particular topic should ignite new questions as well as new ways of carrying out the research.

Methodology

In this section, you must describe, in detail, the methodology used to collect data, make observations, design apparatus, etc. Be sure to describe how the variables will be controlled. Your paper should be detailed enough so that someone would be able to repeat the experiment solely based on information provided in your paper. Detailed photographs or drawings of self-designed equipment, as well as more detailed explanations, must be included in the appendix. Keep in mind that any potential risks and safety precautions that were taken should be described in detail in this section.

Materials
The experimental design can be communicated through a chart, list or paragraph and includes the vital parts of the experiment:

- the independent variable
- the levels of the independent variable
- the dependent variable
- the control
- the repeated trials
- the constants

For a more comprehensive discussion of the parts of the Experimental Design, see the Intel ISEF Student Handbook Overview.

Observations and Analysis of Data
In this section, you will display your findings and discuss the results of your experiment, the procedures used for data analysis and how you summarized the data from various research trials in words. Any unusual observations should also be included in this discussion.

Conclusion/Discussion
This section is the essence of your paper. The conclusion summarizes the major findings, explains the results, compares the findings with other scientific information, suggests improvements and offers recommendations for other experiments.

When writing your conclusion/discussion, *include key facts from your review of the literature* to help explain your results as needed. For instance, describe whether your results suggest a relationship between the independent and dependent variables. If you are doing an engineering or computer science programming project, then you should state whether or not you met your design criteria. Use the Conclusion Section to connect the science discussed in the Introduction to the actual results obtained. The big question that should be answered in the conclusion is ***"why you got the results you did based on the SCIENCE involved".***

It is OK if your results do not support your hypothesis. Try to explain why you think that you obtained different results than what you predicted based on the science of your project. ***Do not alter your results to fit the hypothesis!***

When writing your conclusion, do not just repeat sentences that you used in your introduction. Use the **"science"** of the project to explain your results. Discuss the data that you gathered and explain what it means**:**

- What were your major discoveries or findings? and How did your findings support your hypothesis?
- How did your findings compare with other scientific research or information in science books and magazines?
- How did the data vary between repeated observations of similar events?
- How were your results affected by uncontrolled events?
- How could you improve the experiment or conduct more research in certain

areas?

References/Bibliography

The reference list includes the sources used to design, conduct, and analyze the results of the experiment. It should consist of at least 5 major sources, such as books, journals, science periodicals, etc., which are cited in the text of the paper. These should be written using an acceptable style manual such as the American Psychological Association, The Chicago Manual of Style, or those of the Modern Language Association.

Tip: Citations enable you to provide credit to the ideas of others. In particular, direct quotations, paraphrased arguments and ideas from others require a citation. Websites such as Citation Machine and The Internet Public Library will help you navigate this important feature of your paper.

Abstract

The Abstract is a one-page paper (250 word maximum) that summarizes your complete research plan, implementation, and conclusion. You will submit your abstract during the registration process. You will also display your abstract during the exhibit portion of the Metro Richmond STEM Fair.

Tip: The abstract is often the only item used by the Special Award judges to determine which students they wish to interview, so it is important that it is well done.

Please see the example below:

Advertisers are always touting more powerful and longer lasting batteries, but which batteries really do last longer, and is battery life impacted by the speed of the current drain? This project looks at which AA battery maintains its voltage for the longest period of time in low, medium, and high current drain devices. The batteries were tested in a CD player (low drain device), a flashlight (medium drain device), and a camera flash (high drain device) by measuring the battery voltage (dependent variable) at different time intervals (independent variable) for each of the battery types in each of the devices. My hypothesis was that Energizer would last the longest in all of the devices tested. The experimental results supported my hypothesis by showing that the Energizer performs with increasing superiority, the higher the current drain of the device. The experiment also showed that the heavy-duty non-alkaline batteries do not maintain their voltage as long as either alkaline battery at any level of current drain.

This example was obtained from https://www.sciencebuddies.org/science-fair-projects/science-fair/science-fair-project-sample-abstract