FRAMINGHAM HIGH SCHOOL

Science Project Guide

Honors Biology Program

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2012-2013

Important Dates

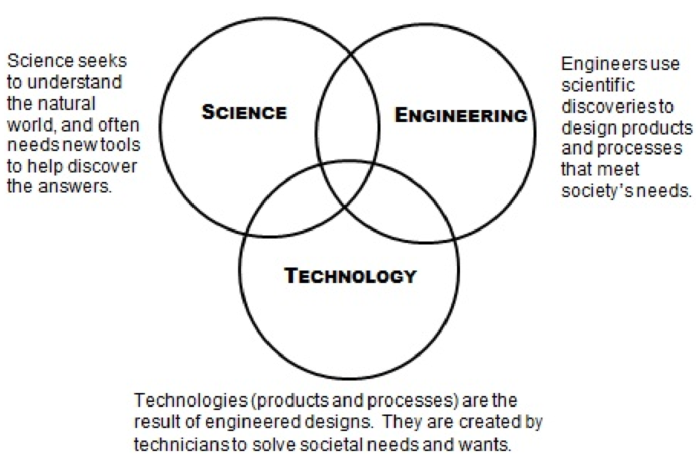
Project Proposal Due: **9 November 2012 (you may submit it early).**

Project Due: **4 February 2013**

Science Fair: **13 February 2013**

Contents

The Relationships among Science, Engineering, and Technology



Overview

You are responsible for conducting either a scientific experiment or an engineering design project.

For the science project, you must:

- Propose an experiment to confirm or disprove a hypothesis
- Perform background research on both the subject you are studying and the experimental techniques you will use. This research is cited and recorded in a laboratory notebook.
- Design and conduct the experiment. The procedure, work, data, and results will be recorded in the laboratory notebook.
- Submit your experiment and results in a written report (in the style of a lab report).
- Present your experiment and results in a five-minute talk and on a three-panel poster.

For the engineering project, you must:

- Choose a design problem that you will solve either by creating a process, prototype, or computer program.
- Research the most appropriate tools, materials, and design to solve the problem. This research is cited and recorded in a research notebook.
- Build an actual process or prototype, or write the computer code to solve the problem.
- Submit your design schematics or code, and an evaluation of how well your design addressed the original problem in a written report (the style of an engineering report is found later in this document).
- Present your project and results in a five-minute talk and on a three-panel poster.

Grading

Your grade is determined by the following criteria:

Experimental Project

- Originality of the hypothesis
- Sophistication of the experiment
- Validity of the experiment
- Quality of the acquired data
- Quality of the data analysis

Engineering Project

- Originality of the concept
- Sophistication/complexity of the design
- Quality of the prototype
- Quality of the analysis of how the prototype fulfills the design goals

The bulk of the grade will be based on your experiment and results as reported to the class through your oral presentation and the poster. The report and notebook will be minor contributors.

Historically, the average grade on this assignment is a C^+.

The science project grade will be 10% of your Term 3 grade.

Choosing a Project

Choosing a good project is usually the most difficult part of this assignment. You can choose to do an experiment in any field of science (not just biology) or an engineering project in any field (process, electrical, mechanical, or chemical engineering; or in computer science).

In the past, students with the most successful projects chose topics that were important to them. Start with something you like. A student who loves the beach did a project on the effect of different breakwaters on slowing beach erosion. An environmentalist studied the effect of pesticides on microorganisms found in pond water. A student with a long-running argument with his parents as to whether watering the garden twice a day was better than once a day finally proved he was right.

Keep these points in mind as you choose a project:

- The project must be either an experiment where you attempt to disprove a hypothesis or an engineering project where you attempt to build a prototype to fulfill a specific project goal. The project cannot be building a model or doing library research.
- The project can be a repeat of a past one, especially if you are using someone else's idea as a starting point for a similar study of your own. Novel projects are given special consideration when grades are assigned. Be careful of using projects from kits: they show very little imagination and require very little effort, and your grade will reflect this.
- The project must be appropriate for a high school honors student. Growing plants in the light or the dark, or baking cookies with or without baking powder are only acceptable in elementary school.
- The project must be doable. In other words, make sure you know how to perform each step, and have all the equipment you need. If you want to study the effect of dissolved oxygen levels on microorganisms at different locations in a river, make sure you know exactly how you are going to measure the dissolved oxygen. Too often, a student will propose an excellent hypothesis, only to discover they have no idea how to perform the experiment.

You can search online for science project ideas (there are many websites devoted to conducting projects), look over lists of projects from past years or from other schools (I have abstract books you can look over), or by asking upperclassmen who have done projects in the past.

Restrictions

For safety, your project cannot involve anything that may be harmful to you or others. This includes any type of explosive compound or device, any type of pathogenic bacteria or virus, or anything involving weapons.

For ethical reasons, you cannot do any project that may harm a vertebrate animal, such as feeding a rat vitamins or foods in great quantities or taking blood or tissue samples.

Projects involving people, including surveys, must be approved by the teacher before you do them. You must get your subject's permission before you do any work with people.

In certain instances, permission to use dangerous chemicals or items may be given if you will be trained and supervised by a professional in the field, and the work is done in a specialized location like a laboratory or shop.

Submitting the Proposal

The proposal is a short paragraph describing your project. It concisely states your hypothesis and how you are going to test it or your engineering project goal (a project goal is to build a device, write a program, or design a system to solve a problem) and how you are going to build it. It need only be a couple of lines. I will review your proposal and make sure the project is of appropriate difficulty, that you have enough of a procedure fleshed out to ensure the project is doable, and that it is safe. Just because I approve a project proposal does not mean you will automatically be assured a good grade. The successful effort you put into the project plays a significant role in your final score.

Once your project is approved, you can start work immediately. If it is rejected, you must either address the flaws and resubmit the proposal or submit an entirely new proposal. You cannot do a project unless it is approved.

Doing the Project

Once your project is approved, you can begin work immediately. Even though you have months to get the work done, and both December and Midterm breaks, I strongly recommend you begin early. This is particularly important if you are doing anything with plants or living specimens like protists and microorganisms—these are notoriously prone to dying at just the wrong time in your project, so you need to leave time to do a second attempt if necessary.

Working with Others

It is expected that you will do the project yourself, with your own hands. If it is determined that others (including your parents or other adults) did work for you, you will get a zero. Others are allowed, even encouraged, to teach you how to use tools and apparatus and to show you how to do new techniques. They can also help you do certain complicated tasks. Nevertheless, the ideas and most of the sweat must be yours. If you have any question about when working with others becomes cheating, talk to me—before you turn the assignment in. Once you submit the work for a grade, no excuse pardons cheating.

Notebook

You will need a bound laboratory notebook to record all of your work. In research labs, the notebook is the most important part of research record keeping. True lab notebooks are often bound so that you cannot remove pages to hide bad data or falsify result, and are written in ink so they cannot be modified. In some labs, they are often signed by a witness at the end of the day to confirm when work was done in case a dispute arises during a patent application or to award credit for making the first discovery.

The notebook needed for the project can be a simple composition book from a stationary store, or even a wire-bound notebook in a pinch.

Figure 1. A simple laboratory notebook

You should record everything you do in your notebook:

- The purpose of your project
- The research you do to gather background information and look for procedures. Remember to cite your sources.
- The detailed procedures you followed
- Any changes you make in the procedure (It is acceptable to amend your procedure if you discover that something does not quite work or if you think of something better.)
- The data you gather
- The conclusions you draw

If you have printouts, photographs or other objects, you can tape or staple these in your notebook rather than recopy them.

Make sure you date the entries you make in your notebook when you do them. The notebook is a living document that is added to every time you work on the project. It should not be filled out at the end.

Sample notebook pages are included at the end of this packet.

Background Research

Do background research on your hypothesis or prototype idea and the procedure you hope to use. Someone may have done a similar project before, and their work may guide you in framing your hypothesis or tell you how to perform a technique to gather data, grow your specimens, or build your project. This is particularly important if you need to raise plants, protists, or prokaryotes as they often require precise growth conditions. It can also give engineers ideas on how to address certain design issues, what materials to use, and techniques to work with them. You are expected to show evidence of background research in your project.

You do background research before you start the experiment.

The Experimental Project: Conducting an Experiment

Far from just memorizing facts and processes, science is an organized, logical way to study the world around us. A well-designed experiment attempts to explain the how and why things behave as they do, without preconceptions, prejudice, or wishful thinking to cloud the results.

We discussed the scientific method at the beginning of the year. One of the goals of this assignment is to test your understanding of how the process works. Make sure you keep the following in mind as you conduct your experiment:

Good experiments should rely on **quantitative data** that is measured in numbers. Avoid qualitative measures like hotter, colder, liked more, liked less, lighter, darker, faster or slower. Be sure to find a valid and accepted way to gather data and analyze results—for example, if you are measuring how many bacteria are in a sample, find out how microbiologists would actually do this rather than make up your own system. All measurements should be in SI units. Remember: your opinion is irrelevant. Your conclusions, based on your data, are very important.

Experiments must be **controlled**. You always compare your hypothesis against the normal condition. At the least, your experiment must have two groups: the control group experiencing normal conditions and your test group. To be sure that this comparison is valid, you must ensure that your two groups are **standardized** in every way except for the variable you are testing. Poorly standardized experiments are often the cause of low grades on projects. Finally, use **large sample sizes** or run your experiment **multiple times** (multiple means more than two). If you are doing a psychological project (which are my most hated of science projects), then you must test a large group of people to ensure that your results are real. When grading your project, consideration will be made if large sample sizes or multiple runs are not possible due to costs or other extenuating conditions, at my discretion.

Find the best way to analyze your data. Advanced students may want to look into statistical tests that can be used to ensure your results are real, and not just normally expected fluctuations in your measurements.

The Engineering Project: Solving a design problem

An engineer sees a problem and designs something or someway to fix it. This could involve creating a new device, synthesizing a chemical, writing a computer program, or even changing the steps in a complicated process to increase efficiency.

Rather than a hypothesis, your engineering project must have a **design goal**. This should be very explicit: a benchmark that you can either meet or not. Examples of good design goals would be to create a robot that can travel to and extinguish a fire, to find a faster way to charge your iPod, or to write a computer program that will graph a type of equation that your calculator cannot. Note that the design goal cannot be simply to build an existing item, like building a radio from a kit. You must be doing something novel, something that requires you to do more than simply follow directions or a blueprint. Many times, you will create a **prototype**. You build this first-of-its-kind device from scratch. You can bring this into school and show it as the major part of your project.

The diagram below shows the engineering design process, which can guide your work. After you identify a problem, research it in greater depth to get a better understanding of the problem and other peoples' solutions. A good place to start in researching other people's work is to search the US Patent Office's (http://uspto.gov) patent database.

Start planning your solution, which may involve making plans or models on paper (2-D modeling) or by building models or devices (3-D modeling). Google has a free design program call SketchUp you may find helpful in making any drawings (http://sketchup.google.com). Once your design is complete, build and test your prototype. Rarely does the first prototype work as you want. One of the key parts of the design process is overhauling and redesigning your prototype to accomplish your goals better.

At the end of the project, revisit your design goal and assess whether you failed to meet, met, or exceeded your goal. Critically evaluate your project. As with an experiment, rely on **quantitative measures** if possible. How much more efficient is your prototype than the current way of doing things? How cost effective is your design?

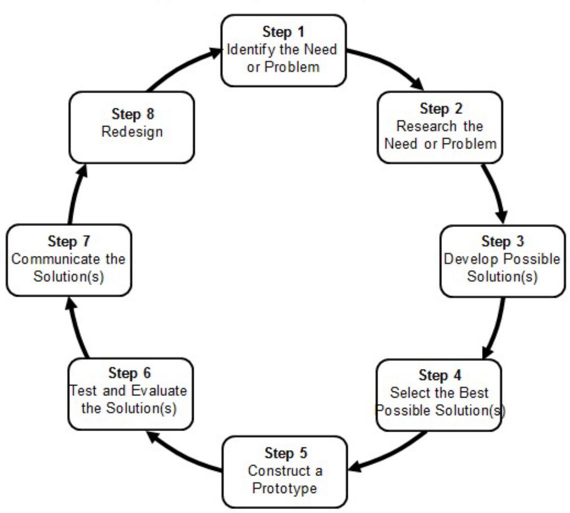


Figure 2. The Engineering Design Process

What if your project doesn't work: dealing with unforeseen problems

Sometimes your design does not progress as you wish, or unexpected issues jeopardize your entire experiment. You will have to deal with these as they come up in your project.

First, understand that disproving a hypothesis is sometimes as important as proving a hypothesis. If you noticed that the number of lily pads growing in a pond near your house appear to be decreasing over the years, and you hypothesize that a chemical your parents and your neighbors add to their lawn is killing the plants, you may design an experiment to test this. You grow batches of lily pads in spring water and in spring water mixed with the lawn chemical. You find no difference. Your hypothesis is incorrect—the chemical is not harming the lily pads. Nevertheless, just because the result is not what you wanted or expected, it is still a good result. You have shown that in this experiment the lawn chemical is NOT detrimental to lily pad growth.

However, there are times when an experiment or design fails utterly and must be discarded and replaced. If you were testing lily pads as above, and the plants in both control and experimental tanks die, you must redo the project. If you are attempting to design a wind turbine that can generate electricity but cannot get the turbine to spin regardless of blade design, you must redo the project or start anew. Part of what I am testing you on is the ability to construct a valid, functional experiment or design.

If you find yourself with a failed experiment, see me right away. We may be able to come up with a way to salvage it, but more likely, you will need to propose a new one. You must get this proposal approved by me before you can begin work. We can probably get the new proposal approved over email to speed up the process.

The most important thing you can do to mitigate this problem is to <u>start early</u>. Do not procrastinate! This is especially important if you are working with living things or plants, which require time to grow and are very sensitive to growing conditions and may die for inexplicable reasons.

Turning in the Project

The notebook and other notes

You will submit all of the research and notes you took during the conduct of your project. Make sure they are bundled and clearly labeled with your name. Engineering projects should have blueprints and schematics of your prototype, if appropriate. [Note: drawing blueprints is a highly specialized skill. I do not expect technically perfect results. Do your best.]

The Report

The experimental project report will follow the same format as your standard lab write-ups, but this time you will be reporting your own experiment and results. The engineering project report is explained in the Appendix.

The introduction will be longer, because you will have to introduce a completely new topic that neither the class nor I know anything about. I would expect this to take about two to four pages. You should use other sources to get detailed information on your topic (at least three sources). You will list the sources in a bibliography at the end of the paper. This section should go into enough detail to show that you have put substantial effort in researching your topic.

The material and methods section will list your experimental procedures. Since you wrote or researched the procedure on your own, this should be a long section. Remember that your protocol should be detailed enough so that another scientist could repeat your experiment. The easiest way to do this is to have a list of supplies used along with a numbered, step-by-step set of instructions detailing how you conducted your experiment

The discussion section interprets your results. What do they actually show? Did they confirm your hypothesis? Did they disprove your hypothesis? Remember that sometimes disproving a hypothesis can be just as important as confirming one. If your data does not turn out the way you expected does not mean that you failed.

Remember to cite your sources; you can use the same style you were taught in your English class.

The Poster

Your poster will be one of the most significant contributors to your project grade. On a three-panel poster, you will present a short summary of the purpose, method, results, and conclusions drawn from your project.

Start with a large title with your title and your name, which should be centered at the top of the middle section.

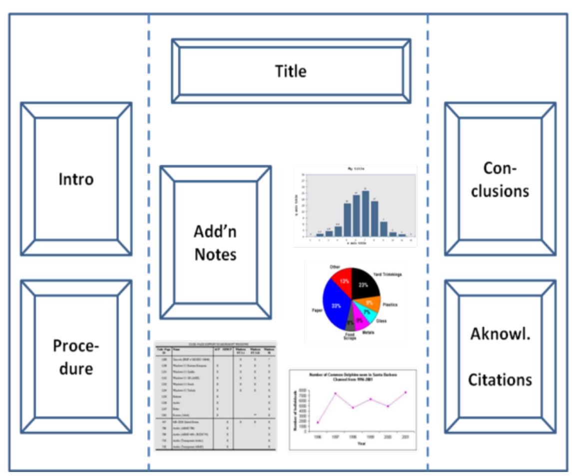


Figure 3. A model of a common poster

On the right-hand side of the poster, place a very brief introduction. The introduction section should introduce your experiment or engineering project and include your hypothesis or design goal. Below it, place the material and methods section. Make sure it is clear enough for a reader to understand the major parts of your experiment, but do not go into detail. Use pictures or diagrams to show important equipment or complicated parts.

The middle of the poster will display your most important results. Clearly show your experimental outcomes. Engineers may put schematics or diagrams of their prototype here. Everyone should put graphs, tables, charts, or diagrams here to show your reader what they need to know.

The left-hand side will contain the discussion section, which will clearly state your conclusions. You can also include additional information like future experiments, acknowledgements, or other miscellaneous information.

The key to a good poster is to make it short and easy to read. Use big fonts that will stand out. All text on our poster should be clearly legible from three feet away. Use few paragraphs and complete sentences. Often, a bullet list is best because it is faster to read.

Make your poster visually appealing. Use color backgrounds, color graphs, or pictures of your experiment. (We have a digital camera that you can sign out and use). However, consider the poster a professional presentation. Imagine it as something you would show to a college professor or boss. You are no longer in elementary school, and the time for crayons and glitter is over.

The Oral Presentation

This oral presentation is short: five minutes maximum, *with no extra time permitted*. This is not a lot of time. Start by introducing your project to the class, giving them enough background research to understand all of the terms and procedures you will use. Give your hypothesis or design goal. Briefly go over your procedure. For the experimental projects, make sure to show your control, how you standardized your experiment, and the sample size and/or number of replicates you ran. For the engineering project, describe how you will set out to achieve your design goal, explaining first the basics of your design and then using a diagram or blueprint to lead the audience through how you accomplished your goal. It is a good idea to highlight any special aspects of your project here, such as equipment built from scratch, a particularly challenging design or construction issue, or a particularly advanced or time-intensive part of your experiment. You can bring pieces of your project in to show your colleagues. The art of self-promotion is an important one to learn early. You want to impress upon your audience that you did some unique work without sounding arrogant.

After describing your procedure, give your results. It is helpful to use your poster as a visual aid. Point out your important findings on the graph or table included on your poster. Interpret the results: if you found that plants in sample A grew taller than those in sample B, explain why you think this is the case. Clearly state your conclusion: use strong statements like “The data show that ….” or “I found that ….” to give your final results and interpretation to the audience. You should always state whether you confirmed or disproved your hypothesis or accomplished your design goal. At the very end of your presentation, your audience should be left with a clear impression of your findings.

After your presentation to the class, you will be asked questions by both your classmates and by me. You must be able to defend your choice of experiments and your interpretation of your results in front of your colleagues.

Some hints on the oral presentation:

- Five minutes is not a lot of time. I will cut you off if you go over time, and if you did not get to your results or conclusion, you will lose points. Keep to the main ideas, and avoid fine details if possible.
- Practice!!! This will give you an idea of the length and clarity of your presentation. One of the practice runs should be in front of your parents or others who do not know the details of your project. After they hear your presentation, they should be able to tell you what your hypothesis was, briefly describe your methods, and should definitely be able to repeat clearly back to you your conclusions.
- Do not read from your poster. Keep your eyes on the class. You may refer to the poster, and you should definitely point things out on the graphs or tables, but do not rely on it for your entire presentation. Your talk should be extemporaneous: you can refer to notes like your poster and note cards, but it should not be read from a script.

October 1, 2000

Researched ways to grow bacteria. Googled how to make petri dishes. Found good sites:

- www.website.com- good recipe for agar
- www.website.com- sold the nutrient agar plates I need.

---Will probably buy them instead of making them

Record your early work researching your topics, including web searches

October 13, 2000

Called Dr. John Doe (555-123-1234) at UMASS Amherst, and told him about my project. Asked him how much bacteria are normally found in the bathroom. He said there should be a lot, and that it isn't bad--most bacteria are harmless or even helpful. He said I could do tests on the bacteria to see if they are the good kind or bad kind. He will email me how to do the tests.

Record the information from all sources, including personal interviews.

Bought 20 nutrient agar plates from www.website.com

October 14, 2000

Dr. Doe emailed me the tests. They are attached below. **[Staple or tape the email into your lab note book]**

Attach print outs and other loose paper firmly to your notebook

October 15, 2000

Researched ways to count the number of bacteria on my plates.
Looked in books from Dr. Langdon's room: Book Title, author, publisher, year, pages used.
[Cite the book]

Found a good protocol on line at www.website.com- printed out protocol and taped it below.

[Cut out and tape or staple anything helpful into your notebook. Make sure you note exactly where it came from.]

November 1, 2000

Started experiment.

1. Took 4 nutrient agar petri plates.
2. Dipped sterile cotton swab in sterile water. Rubbed the swab for five seconds over
   a. Toilet bowl rim near the front
   b. Bathroom sink bottom near drain
   c. Cold water faucet on bathroom sink.
   d. Nothing--just dipped the swab in the sterile water to act as a control.
3. Rubbed the swab completely over the agar surface on one plate each. Labeled them:
   a. Toilet
   b. Sink
   c. Faucet
   d. Control
4. Put them in 30°C incubator for two days.

Completely and accurately record your procedure as you perform the experiment.

November 3, 2000

Took out plates:

Plate A (Toilet): covered with colonies, looked like small white dots. Took picture with phone. Counted 79 colonies.

Plate B (Sink): had the most colonies. Many different colors and shapes. Took picture with phone. Counted 190 colonies.

Accurately record your results. Use photos or video when you can.

....

[Attach the Pictures]

November 5, 2000

My results show....because .... **[give your conclusion, and make sure it is supported by data]**

Always formally state your conclusion.

Appendix II: A very brief guide to writing engineering reports

Engineering reports often differ from experimental reports because little data was gathered and few experiments performed. Rather, you often designed a device to address a design goal. Your report describes your prototype and how well it met your goal.

Abstract or Executive Summary

The abstract is a summary of the entire engineering report. It appears first in your paper, and is the only part that is single-spaced. The summary should be brief, often no more than one-quarter or one-half a page. The abstract should:

- Gives the research problem and/or main objective of the research
- Indicates the methodology used (what you did or what you measured)
- Presents the main findings and conclusions

Introduction

The introduction explains the research problem and its context. You should explain why your project is both new and relevant: why your project is better than any existing device to solve the problem.

Your introduction should show clear evidence of outside research, especially if you omit the optional literature review. Always make sure you cite your sources.

At the very least, the introduction should:

- Explain the importance of the problem (Why does it matter? Why is more information needed?)
- Explain the reason and goals for study
- Explain the limitations of the research performed (What your device cannot or will not do)

Literature Review

The literature review is optional. Many young students incorporate the information from their background research in their introduction.

The literature review summarizes and evaluates the literature that you have used in your study . for each source you used, explain:

- How that literature has contributed to your area of research
- The strengths and weaknesses of previous studies
- How that literature informs your own research and understanding of the research problem

Methodology or Design

This portion of the report describes either what you built or what you measured for your project. If you measured anything, here you explain how data was gathered or generated and how it was analyzed.

If this is a design project, you describe the creation of your prototype, and include and blueprints and circuit diagrams needed to understand your project.

Results

Here you will visually and textually represents research findings. To visually represent your results, you can use graphs, tables, diagrams, or charts. The text should point out the most significant portions of research findings, indicate key trends or relationships, and highlight expected and/or unexpected findings.

Discussion

Here you evaluate and comment on your research results. It could include:

- Explanation for your results
- Comments on unexpected results, offering hypothesis for them
- Comparison to literature and other similar devices
- Does your research confirm previous studies? Deviate from them?
- Explanation for how info can be applied in broader context

Conclusion or Summary

In the summary or conclusion, you briefly address these points:

- What was learned through research
- What remains to be learned
- Weaknesses and shortcomings of study
- Strengths of study
- Possible applications of study (how it can be used)
- Recommendations

Citations

Cite sources whenever you are quoting, paraphrasing, or summarizing work that is not your own.

Summarized from: Purdue Writing Lab — OWL Online Writing Lab, Purdue University, owl.english.purdue.edu