Your Question

Before learning how to narrow down the question for your YSP project, it's important to have a brief introduction to the scientific method of performing an experiment.

Overview of the Scientific Method

The scientific method is a process for experimentation that is used to answer questions and explore observations.


Rachel Spencer (2006); Photo taken by Damilola Coker

Scientists use an experiment to search for **cause and effect** relationships in nature. In other words, they design an experiment so that changes to one item *cause* something else to vary in a predictable way. These changing quantities are called **variables**. Variables are a key element of the scientific method.

Here is an overview of the scientific method that you will need to understand in order to complete your YSP project. Don't worry about having to learn it all at once. Every week or two, you'll have an assignment that involves just one step in this process, and at that time, we'll give you a more complete explanation, including examples and samples.

1. **Stating the Question:** What is it that you are trying to find out from your experiment? What is it that you are trying to achieve?

2. **Research Your Topic:** Investigate what others have already learned about your question. Gather information that will help you perform your experiment.

3. **State Your Hypothesis:** After having thoroughly researched a topic, you should have some prediction about what you think will happen in your experiment. This educated guess concerning the outcome is called your hypothesis. You must state your hypothesis in a way that you can readily measure.

4. **Test Your Hypothesis by Doing an Experiment:** Now that you have come up with a hypothesis, you need to develop a procedure for testing whether it is true or false. This involves changing one variable and measuring the impact that this change has on other variables. When you are conducting your experiment, you need to make sure that you are only measuring the impact of a single change.

Scientists run experiments more than once to verify that results are consistent. Each time that you perform your experiment is called a **run** or a **trial**.

5. **Analyze Your Results:** At this stage, you want to be organizing and analyzing the data that you have collected during the course of your experiment in order to summarize what your experiment has shown you.

6. **Draw Your Conclusion:** This is your opportunity to explain the meaning of your results. Did your experiment support your hypothesis? Does additional research need to be conducted? How did your experiment address your initial question and purpose?

7. **Report Your Results and Conclusion:** Since you are performing an experiment for the Young Scholars Program, you will write a report and prepare a presentation so that others can share in your discoveries.

Your Question

The Assignment

Usually, once you have found a topic area that interests you, you would try to narrow down your topic to a specific question by finding some inspiration through magazines, newspapers, science textbooks, TV science documentaries, science fair projects, or the Internet. You would normally also think about your own experiences and things that you may have observed that sparked a question in your mind. However, being that you have been assigned to assist with a research project that is already in progress, you should verify the question with your YSP mentor.

Remember, a science project is all about finding an answer to a question. So, the topic should be narrow enough for you to answer with a simple experiment. Imagine that you are working in robotics, for example, and researching how robots work. To develop a good topic for an experiment, you need to ask as specific a question as possible. For example: How much current does a robot's arm use to lift different weights?

To help ensure that you have developed a good science project question, please complete the "What Makes a Good Science Project Question?" worksheet. **Please return to the YSP Coordinator by Friday, June 8, 2007**.

More Examples

These are examples of project questions:

- Does water purity affect surface tension?
- Which material is the best insulator?
- How does arch curvature affect load carrying strength?
- How do different foundations stand up to earthquakes?
- What sugars do yeast use?
- Does fire stimulate plant growth?

What Makes a Good Science Project Question?

Due Friday, June 8, 2007

Name: ______________________________

1. Is the topic interesting enough to read about, and then work on for the next month? Explain.

____
____
____

2. Can you find at least 3 sources of written information on this topic? What are they?

____
____
____

3. Can you measure changes to the important variables using a number that represents a quantity such as a count, length, width, weight, voltage, time, etc.? Or, just as good, is your variable one that is simply present or not present? For example,

   - Lights ON in one trial, then lights OFF in another trial,
   - USE fertilizer in one trial, then DON'T USE fertilizer in another trail.

   What are your variables? How will you measure them? (For more information on variables, see the section entitled "Variables and Hypothesis".)

____
____
____

4. Can you control other factors that might influence the variables, so that they do not interfere with your experiment? How?

____
____
____

5. What materials and/or equipment will you use to complete your project? Describe how each piece will be used.

____
____
____

The materials contained in this document originated from www.sciencebuddies.org.

Background Research Plan and Bibliography

Outline

- Overview
- Why the Need for Background Research?
- Making a Research Plan: How to Know What to Look For
- How to Find Information
- Your Bibliography
- Your Assignment

Damilola Coker (2006); Photo taken by Damilola Coker

Overview

As you know, a bibliography is a listing of the books, magazines, and Internet sources that you use in designing, carrying out, and understanding your YSP project. But, you develop a bibliography only after first preparing a research plan—a roadmap of the research questions you need to answer.

Why the Need for Background Research?

So that you can design an experiment, you need to research what techniques and equipment might be best for investigating your topic. Rather than starting from scratch, savvy investigators want to use their library and Internet research to help them find the best way to do things. You want to learn from the experience of others rather than blunder around and repeat their mistakes.

Research is also important to help you understand the theory behind your experiment. In other words, research helps you understand why your experiment turns out the way it does. You do library and Internet research so that you can make a prediction of what will occur in your experiment, and then whether that prediction is right or wrong, you will have the knowledge to understand what caused the behavior you observed.

Making a Research Plan: How to Know What to Look For

When you are driving a car there are two ways to find your destination: drive around randomly until you finally stumble upon what you're looking for OR look at a map before you start. (Which way do your parents drive?)

Finding information for your background research is very similar. But, since libraries and the Internet both contain millions of pages of information and facts, you might never find what you're looking for unless you start with a map! To avoid getting lost, you need a plan.

Keywords

The place to start building your plan is with the question for your YSP project (see, we did that first for a reason). Let's imagine that you have asked this one:

Question: Does drinking milk help decrease spiciness better than water or Pepsi?

Begin by identifying the keywords and main concepts in your question. In this case keywords would be:

- Milk
- Spiciness
- Pepsi
- Water

That's pretty easy! Now, what might be some of the main concepts that relate to these keywords? Let's think about spiciness first. You're going to do a science experiment, so knowing that a spicy food tastes "hot" is probably not sufficient. Hmmmm, this is a little tougher than finding the keywords.

Question Words Table

The secret is to use the "question words" (why, how, who, what, when, where) with your keywords. Ask why things happen, ask how things happen, ask what causes things to happen, ask what the properties of key substances are. Filling in a little table can help. Let's do it for our keyword spiciness:

Question Word	Fill Your Keywords (or Variations on Your Keywords) into the Blanks *These are just samples to get you thinking; there are always many more questions and the most important ones for your project may not be in the list!*	My Possible Questions to Research	Relevant?
Why	Why does ________ happen? Why does ________ ________?	Why does spiciness happen? Why do spicy foods taste hot?	No Yes
How	How does ________ happen? How does ________ work? How does ________ detect ________? How does one measure ________?	How does the tongue detect spiciness? How does one measure spiciness?	Yes Yes
Who	Who needs ________?	Who needs spiciness?	No
What	What causes ________ to increase (or decrease)? What is the composition of _________? What are the properties and characteristics of ________? What is the relation between _______ and ________?	What causes spiciness to increase (or decrease)? What are the properties and characteristics of spicy substances?	Yes Yes
When	When does ________ cause ________?	When does spiciness cause upset stomachs?	No
Where	Where does ________ occur?	Where in the body does spiciness occur?	Yes

Those look like pretty good questions to research because they would enable us to make some predictions about an experiment. But what's that column in the table called "Relevant?"

You can always find more information to research, but some questions just don't have anything to do with the experiment you will define and perform. Questions that **will** help you design and understand your experiment are called *relevant*. Questions that **will not** help you design and understand your experiment are called *irrelevant*. Our table of question words is a great way to generate ideas to research, but some of them will be irrelevant and we just throw those out. Some of those irrelevant questions might be very interesting to you; they just don't belong as part of your science project. We have to focus our efforts on what we feel is most important, or another way of looking at it, let's not spend time researching anything we don't need to. (I'm sure you have other things you'd like to do, too!)

For a good example of how the question word table can generate irrelevant questions, let's just look at some possible questions if we fill out the table for another one of our sample keywords: milk.

- Why does milk happen?
- How does milk happen?
- Who needs milk?
- What causes milk to increase (or decrease)?
- What is milk composed of?
- What are the properties and characteristics of milk?
- Where does milk occur?

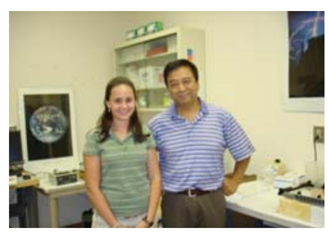
If we research every one of those questions we'll be studying farms, cows, cow udders, baby cows, and what cows eat. Holy flying cows! That information is definitely irrelevant to our project question: Does drinking milk help decrease spiciness better than water or Pepsi?

Even so, in that crazy list of cow science, there are two research questions that look relevant:

- What is milk composed of?
- What are the properties and characteristics of milk?

Sometimes you won't be sure whether a question is relevant or not, and that's always a good time to get the opinion of more experienced people like your YSP mentors, YSP mentor assistants, and parents. In fact, the research plan is a very important step of your project and the experience of your YSP mentor(s) can be super valuable. Two or three heads are always better than one! Even with all that help, you may not be sure whether something is relevant until after you have done your experiment, so don't let it bother you if that's the case.

Talk to People with More Experience: Networking



Lauren Hill (2006); Photo taken by Lauren Hill

As you can see with the two above examples, spiciness and milk, the question word table will work better for some keywords than others. You might have a project question where none of the keywords generate relevant questions. Yikes! What do you do then?

One of the most important things you can do is talk to other people with more experience than yourself: your YSP mentors, YSP mentor assistants, and parents. This is called "networking." Some of these people will have had classes or work experience that involved studying the science involved in your project. Ask them, "What science concepts should I study to better understand my project?" Better yet, be as specific as you can when asking your question. Even experts will look puzzled if you ask a question that is so generic it leaves them pondering where to start. Instead of asking, "How do airplanes fly," try asking, "What physical forces are involved in the flight of an airplane," or "What role do propellers play in the flight of a helicopter?" (After all, there's gotta be something that causes that hunk of metal to go up, right?)

For example, let's imagine your YSP project question is: Does the velocity of a roller coaster car affect whether it falls off a loop? If you ask someone who has studied physics in high school or college, they will tell you to ask the research question, "What is centripetal force?"

Background Research Plan and Bibliography

Sometimes there is even a specialized area of science that studies questions similar to the one for your project. Believe it or not, there are actually people who study "roller coaster physics." (Is that a cool job or what?) Often a good topic to research is simply the specialized area of science that covers your project. For the roller coaster example you would research "roller coaster physics."

How do you find the area of science that covers your project? You guessed it, network with your YSP mentors, parents, and teachers. And by the way, networking is something many adults don't expect students to be very good at, so you can probably surprise them by doing a good job at it. The very best networkers, of course, enjoy the spoils of victory. In other words, they get what they want more quickly, efficiently, and smoothly.

The reality is we have all networked at some point in our lives. Remember how you "networked" with your mom to buy you that cool water gun, or "networked" with your grandpa to buy you that video game you always wanted? Well, now you are "networking" for knowledge (which is a very good thing to network for, by the way). Train yourself to become a good networker, and you might just end up with a better YSP project (and don't forget that you'll get a little smarter too in the process). So take our advice: work hard, but network harder.

Sample Research Plan

Research Plan for the Project Question: Does drinking milk help decrease spiciness better than water or Pepsi?

Keywords --

- Milk
- Spiciness
- Pepsi
- Water

Research questions --

- Why do spicy foods taste hot?
- How does the tongue detect spiciness?
- How does one measure spiciness?
- What causes spiciness to increase (or decrease)?
- What are the properties and characteristics of spicy substances?
- Where in the body does spiciness occur?
- What is the composition of milk, Pepsi, and water?
- What are the properties and characteristics of milk, Pepsi, and water?

Science concepts and/or areas of science --

- Taste buds

Summary

Background research is necessary so that you know how to design and understand your experiment. To make a list of questions and concepts to research:

Background Research Plan and Bibliography

1. Identify the keywords in the question for your science fair project.
2. Use a table with the "question words" (why, how, who, what, when, where) to generate research questions from your keywords.
3. Throw out irrelevant questions.
4. Network with other people with more experience than yourself: your mentors, parents, and teachers. Ask them: "What science concepts should I study to better understand my project?" and "What area of science covers my project?" Better yet, ask even more specific questions.

How to Find Information

No matter how you do your research, record your sources and take good notes as you go. Your YSP mentor should be able to offer you some tips.

Library Research

Often the best place to start your research is by looking up your keywords in an encyclopedia, dictionary, or textbook. Your library may have specialized dictionaries for different topics like science, sports, music, and so on, which offer more complete information than a regular dictionary. Ask your reference librarian to help you.

"Read the background information and note any useful sources (books, journals, magazines, etc.) listed in the bibliography at the end of the encyclopedia article or dictionary entry. The sources cited in the bibliography are good starting points for further research. . . . By using this technique of routinely following up on sources cited in bibliographies, you can generate a surprisingly large number of books and articles on your topic in a relatively short time" (Engle 2003).

You can also check the subject headings of books and articles as you look them up in the library catalog. Check to see if other books in the same subject area contain relevant information.

Periodicals are printed material like magazines and newspapers. Depending on your topic, they may also contain useful information. You can look up your keywords in a printed index such as the *Reader's Guide to Periodical Literature*, which covers popular magazines. Your library may have a number of periodical indexes in both printed and online forms. Check with your reference librarian.

Internet Research

There are two primary ways to search for information on the Internet. The first is to use a search engine such as Google:

http://www.google.com

Search engines try to index everything on the Internet. The second way to search is using a subject portal. Subject portals list just a small portion of the information on the Internet, but the sites listed have been checked for relevance. Two popular subject portals are:

Librarians' Index to the Internet

WWW Virtual Library

Enter your keywords one at a time to search for information in search engines and subject portals.

If you want some advanced tips on using the Internet to find information, the Teaching Library at the University of California at Berkeley offers this tutorial:

Background Research Plan and Bibliography

http://www.lib.berkeley.edu/TeachingLib/Guides/Internet/FindInfo.html

Finding Too Much or Too Little Information

If you are finding too much information, for example pages and pages of irrelevant hits on Google or a periodical index, you need to narrow your search. You can narrow your search by borrowing some of the terms in your research questions. For example, let's imagine that searching on "milk" brings up too much irrelevant information about cows. Here are the research questions we listed having to do with milk:

- What is the composition of milk, Pepsi, and water?
- What are the properties and characteristics of milk, Pepsi, and water?

Try searching on:

- milk composition
- milk properties characteristics

This will narrow your search, and hopefully give your more relevant results.

If you aren't finding enough information, you need to simplify your search. Let's imagine that searching on "measuring spiciness" isn't finding what you want. Try searching on:

- measure spiciness
- spiciness
- spice

Most online search engines and periodical guides have instructions about how to narrow and broaden searches. Read the instructions! For example, here's where Google talks about how to improve your searches:

http://www.google.com/help/refinesearch.html

Too Complicated or Too "Babyish" Information

Sometimes the information you find will be relevant, but either too complicated given your science background or too babyish. This is a problem that we all experience. Just keep looking and ask for advice if you're really stuck.

Your Goal

Never forget, the goal of your searching is to find information to answer the research questions you asked about your topic. Don't stop looking until you have sources that will answer your questions! Be sure to ask for help from your YSP mentors, YSP mentor assistants, and parents if you're having trouble.

Summary

How to find information:

1. Find and read the general information contained in an encyclopedia, dictionary, or textbook for each of your keywords.

2. Use the bibliographies and sources in everything you read to find additional sources of information.

3. Search periodical indexes.

4. Search the Internet.
5. Broaden your search by adding words to your search terms. Narrow your search by subtracting words from or simplifying your search terms.

. Your Bibliography

You should have a minimum of three written sources of information about your topic from books, encyclopedias, and periodicals. You may have additional information from the Web if appropriate.

Examples

There are standards for documenting sources of information in research papers. Following are standard formats and examples for basic bibliographic information.

Books

Format: Author. *Title: Subtitle*. Place of publication: Publisher, Date.

Examples: Allen, Thomas B. *Vanishing Wildlife of North America.* Washington, D.C.: National Geographic Society, 1974.

Searles, Baird and Martin Last. *A Reader's guide to Science Fiction.* New York: Facts on File, Inc., 1979.

Magazine & Newspaper Articles

Format: Author. "Title of Article." *Title of Periodical* Volume # (Date): Pages.

Examples: Kanfer, Stefan. "Heard Any Good Books Lately?" *Time* 113 (21 July 1986): 71-72.

Kalette, Denise. "California Town counts Down to Big Quake." *USA Today* 9 (21 July 1986): sec. A:1.

Website or Webpage

Format: Author (if available). "Title of page." Editor (if available). Date (if available). Institution. [cited Access Date]. URL. *(simply omit any information that you do not have)*

Examples: Devitt, Terry. "Lightning injures four at music festival." August 2, 2001. The Why? Files. [cited 23 January 2002]. http://whyfiles.org/137lightning/index.html.

Article from an Encyclopedia

Format: Author. "Title of Article." *Title of Encyclopedia*. Date.

Examples: Pettingill, Olin Sewall, Jr. "Falcon and Falconry." *World Book Encyclopedia.* 1980.

Your Assignment

Please complete the “Background Research Plan” worksheet and “Bibliography” worksheet. **Please return <u>both</u> worksheets to the YSP Coordinator by Friday, June 15, 2007**.

Background Research Plan

Due Friday, June 15, 2007

Name: ____

1. What is the question that you are going to try to answer with an experiment?

____

____

2. List the keywords and phrases from your question and the topic in general. (Hint: Use an encyclopedia to help you)

______________________ ______________________ ______________________

______________________ ______________________ ______________________

______________________ ______________________ ______________________

3. Now use your keywords to build some questions to guide your background research. Develop at least two or three from each "question word." Don't worry about whether you already know the answer to the question—you'll find the answers when you do your background research. And don't forget to "network" with knowledgeable adults who can help guide you toward good materials!

Question Word	**Possible Questions (you can think of others)**	**Substitute your keywords (or variations of your keywords) for the blanks in the previous column. Write down the relevant questions and use them to guide your background research.**
Why	Why does ________ happen? Why does ________ ________? Why ___________________________________?	
How	How does ________ happen? How does ________ work? How does ________ detect ________? How does one measure ________? How do we use _________? How ___________________________________?	
Who	Who needs ________? Who discovered __________? Who invented _________? Who ___________________________________?	

What	What causes ________ to increase (or decrease)? What is _________ made of? What are the properties and characteristics of ________? What is the relation between _______ and ________? What do we use ________ for? What ____?	
When	When does ________ cause ________? When was _________discovered? When ____?	
Where	Where does ________ occur? Where does ________ get used? Where _______________________________________?	

4. To analyze the results from experiments you might need to know some key formulas or equations. Think about your own experiment and write down any step or task that requires a formula or equation. Don't worry about whether you already know what the formula or equation is—you'll find the actual equation when you do your background research.

   List steps or tasks that may require a formula or equation:

   ___________________ ___________________ ___________________
   ___________________ ___________________ ___________________
   ___________________ ___________________ ___________________

5. In addition to the "Who" and "What" questions you've answered for your Questions Word Table, please answer the following:
   a. Describe other persons/departments/entities/universities involved in this research.

   b. Explain who or what will be affected by this research and how.

   c. Describe what aspect of this research they were involved in or how they contributed to this research.

Bibliography Worksheet

Due Friday, June 15, 2007

Name: ___________________________________

Note: You won't fill in every item depending on the type of source.

This source is a: Book Magazine Newspaper Website Other_______________________		
Author's Last Name	First Name	Middle Initial
Date Published	Title of Publication/Website	
Title of Article (periodicals, encyclopedia, websites)		
Place Published (books only)	Publisher (books only)	Editor (if applicable)
Edition (if applicable)	Volume Number (periodicals/encyclopedia)	Page Number(s)
Website is a Company Organization Government Newspaper/Magazine Other ___________________		
The URL is http:// (websites only)		Last Date of Access (websites only)

This source is a: Book Magazine Newspaper Website Other_______________________		
Author's Last Name	First Name	Middle Initial
Date Published	Title of Publication/Website	
Title of Article (periodicals, encyclopedia, websites)		
Place Published (books only)	Publisher (books only)	Editor (if applicable)
Edition (if applicable)	Volume Number (periodicals/encyclopedia)	Page Number(s)
Website is a Company Organization Government Newspaper/Magazine Other ___________________		
The URL is http:// (websites only)		Last Date of Access (websites only)

This source is a: Book Magazine Newspaper Website Other_______________________		
Author's Last Name	First Name	Middle Initial
Date Published	Title of Publication/Website	
Title of Article (periodicals, encyclopedia, websites)		
Place Published (books only)	Publisher (books only)	Editor (if applicable)
Edition (if applicable)	Volume Number (periodicals/encyclopedia)	Page Number(s)
Website is a Company Organization Government Newspaper/Magazine Other ___________________		
The URL is http:// (websites only)		Last Date of Access (websites only)

Review of Literature

The report called the Review of Literature is the part of the project where students learn the most. So, the paper you are preparing to write is super valuable.

Damilola Coker (2006); Photo taken by Damilola Coker

What Is a Review of Literature?

The short answer is that the Review of Literature is a report summarizing the answers to the research questions you generated in the previous assignment. It's a review of the relevant "literature" (books, magazines, Web sites) discussing the topic you want to investigate.

The long answer is that the Review of Literature discusses techniques and equipment that are appropriate for investigating your topic. And, the Review of Literature summarizes the theory behind your experiment. You should be able to understand why your experiment turns out the way it does. You do library and Internet research so that you can make a prediction of what will occur in your experiment, and then whether that prediction is right or wrong, you will have the knowledge to understand what caused the behavior you observed.

If this sounds to you a lot like the reasons we gave for doing background research, you're right! The Review of Literature is simply the "write up" of that research.

Many science experiments can be explained using mathematics. As you write your Review of Literature, you'll want to make sure that you include as much relevant math as you understand. If a simple equation describes aspects of your project area, include it.

Note Taking

As you read the information in your bibliography, you'll want to take notes. Some teachers recommend taking notes on note cards. Each card contains the source at the top, with key points listed or quoted underneath. Others prefer typing notes directly into a word processor. No matter how you take notes, be sure to keep track of the sources for all your key facts.

When and How to Footnote or Reference Sources

When you write your Review of Literature you might want to copy words, pictures, diagrams, or ideas from one of your sources. It is OK to copy such information as long as you footnote or reference it. If the information is a phrase, sentence, or paragraph, then you should also put it in quotation marks. A reference and quotation marks tell the reader who actually wrote the information.

Parenthetical referencing (also known as author-date citation) is an accepted way to footnote information you copy. Parenthetical referencing is easy. Simply put the author's last name, the year of publication, and page number (if any) in parentheses after the information you copy.

Make sure that the source for every item copied appears in your bibliography.

Examples of Parenthetical References

"If you copy a sentence from a book or magazine article by a single author, the reference will look like this. A comma separates the page number (or numbers) from the year" (Bloggs 2002, 37).

"If you copy a sentence from a book or magazine article by more than one author, the reference will look like this" (Bloggs and Smith 2002, 37).

Review of Literature

"Sometimes the author will have two publications in your bibliography for just one year. In that case, the first publication would have an 'a' after the publication year, the second a 'b', and so on. The reference will look like this" (Nguyen 2000b, 72-73).

When the author is unknown, "the text reference for such an entry may substitute the title, or a shortened version of the title for the author" (The Chicago Manual 1993, 654).

"Some sources will not have page numbers" (Han 1995).

Credit Where Credit Is Due!

When you work hard to write something, you don't want your friends to loaf and just copy it. Every author feels the same way.

Plagiarism is when someone copies the words, pictures, diagrams, or ideas of someone else and presents them as his or her own. When you find information in a book, on the Internet, or from some other source, you MUST give the author of that information credit in a footnote. If you copy a sentence or paragraph exactly, you should also use quotation marks.

Your Assignment

Summarize the answers to your research questions in a paper that's a minimum of 700 words long (about 1-2 typed pages). Please view the paper entitled, “Which Battery is Better?” at the following website:

http://www.sciencebuddies.org/mentoring/project_sample_research_paper.pdf

It may be useful in providing an example of a well written literature review. **Please complete and submit your literature review to the YSP Coordinator by Friday, June 22, 2007.**

Variables & Hypothesis

Variables

Scientists use an experiment to search for **cause and effect** relationships in nature. In other words, they design an experiment so that changes to one item *cause* something else to vary in a predictable way.

These changing quantities are called **variables**, and an experiment usually has three kinds: independent, dependent, and controlled.

The **independent variable** is the one that is changed by the scientist. In an experiment there is only one independent variable.

As the scientist changes the independent variable, he or she **observes** what happens.

Erika Martinez (2006); Photo taken by Damilola Coker

The **dependent variable** changes in response to the change the scientist makes to the independent variable. The new value of the dependent variable is *caused* by and *depends* on the value of the independent variable. For example, if you open a faucet (the independent variable), the quantity of water flowing (dependent variable) changes in response--the water flow increases. The number of dependent variables in an experiment varies, but there is often more than one.

Experiments also have **controlled variables**. Controlled variables are quantities that a scientist wants to remain constant, and he must observe them as carefully as the dependent variables. For example, if we want to measure how much water flow increases when we open a faucet, it is important to make sure that the water pressure (the controlled variable) is held constant. That's because both the water pressure and the opening of a faucet have an impact on how much water flows. If we change both of them at the same time, we can't be sure how much of the change in water flow is because of the faucet opening and how much because of the water pressure. Most experiments have more than one controlled variable. Some people refer to controlled variables as "constant variables."

Variables & Hypothesis

Some Very Simple Examples of Variables

Question	Independent Variable	Dependent Variables	Controlled Variables	Comments
How much water flows through a faucet?	Water faucet opening (closed, ½ open, fully open)	Volume of water flowing measured in liters per minute	Water pressure (how much the water is "pushing")	A better measure of the independent variable would be to find area of the opening in the pipe in square centimeters.
How fast does a candle burn?	Time measured in minutes	Height of candle measure in centimeters	• Use same type of candle for every test • Wind – make sure there is none	In this case, time is what causes the dependent variable to change. The scientist simply starts the process, then observes and records data at regular intervals.
Does the fertilizer make a plant grow bigger?	Amount of fertilizer measured in grams	• Growth of the plant measured by its height • Growth of the plant measured by the number of leaves	• Same plants • Same soil • Same size pot • Same amount of water and light • Make measurements of growth at the same time	
Does an electric motor turn faster if you increase the voltage?	Voltage of the electricity supplied to the motor measured in volts	Speed of rotation measured in RPMs	• Same motor for every test • Same load on the motor	

Variables & Hypothesis

Hypothesis

After having thoroughly researched a topic, you should have some prediction about what you think will happen in your experiment. This educated guess concerning the outcome is called your hypothesis.

The hypothesis is worded so that it can be tested in your experiment. Do this by expressing the hypothesis using your independent variable (the variable you change during your experiment) and your dependent variable (the variable that changes in response and *depends* on changes in the independent variable). Not only must you incorporate all these variables in your hypothesis, but you also must express them in a way that you can readily measure.

For example: "My hypothesis is that doubling the opening created by the faucet [independent variable] will double the flow of water [dependent variable]."

Not every question can be answered by the scientific method. The hypothesis is the key. If you can state your question as a testable hypothesis, then you can use the scientific method to obtain an answer.

Is all science accomplished using this same method that is taught in schools and emphasized at science fairs? Should you worry if you end up disproving your hypothesis? Actually, the answers are no it's not, and no don't worry if you disprove your hypothesis.

Your Assignment

Complete the "Grading Yourself" section of this lesson. Type your variables (carefully labeling each of the three different types) and hypothesis on a Microsoft PowerPoint slide.

Variables & Hypothesis

Grading Yourself

What Makes for Good Variables?	For Good Variables, You Should Answer "Yes" to Every Question
The independent variable is measurable?	Yes / No
You can change the independent variable during the experiment?	Yes / No
You have identified all relevant dependent variables, and they are all caused by and depend on the independent variable?	Yes / No
All dependent variable(s) are measurable?	Yes / No
You have identified all relevant controlled variables?	Yes / No
All controlled variables can be held constant during the experiment?	Yes / No

What Makes a Good Hypothesis?	For a Good Hypothesis, You Should Answer "Yes" to Every Question
The hypothesis is based on information contained in the review of literature?	Yes / No
The hypothesis includes the independent and dependent variables?	Yes / No
You have worded the hypothesis so that it can be tested in the experiment?	Yes / No

Materials List & Procedure

Materials List

What type of equipment will you need to complete your experiment?

Make a materials list being as specific as possible, and be sure you can get everything you need before you start. Visit our Supplies & Materials Web page for tips on places to purchase some of the harder to find items that you may have on your list.

A Good Materials List Is Very Specific	**A Bad Materials List**
500 ml of de-ionized water	Water
Stopwatch with 0.1 sec accuracy	Clock
AA alkaline battery	Battery

Procedure

Now that you have come up with a hypothesis, you need to develop a procedure for testing whether it is true or false. This involves changing your independent variable and measuring the impact that this change has on the dependent variable. When you are conducting your experiment, you need to make sure that the only thing you change is the independent variable so that you are only measuring the impact of that single change. All the controlled variables must remain constant.

Scientists run experiments more than once to verify that results are consistent. In other words, you must verify that you obtain essentially the same results every time you repeat the experiment with the same value for your independent variable. This insures that the answer to your question is not just an accident. Each time that you perform your experiment is called a **run** or a **trial**.

Every good experiment also **compares** different groups of trials with each other. Such a comparison helps insure that the changes you see when you change the independent variable are in fact caused by the independent variable. There are two types of trial groups: experimental groups and control groups.

The **experimental group** consists of the trials where you change the independent variable. For example, if your question asks whether fertilizer makes a plant grow bigger, then the experimental group consists of all trials in which the plants receive fertilizer.

In many experiments it is important to perform a trial with the independent variable at a special setting for comparison with the other trials. This trial is referred to as a **control group**. The control group consists of all those trials where you leave the independent variable in its natural state. In our example, it would be important to run some trials in which the plants get no fertilizer at all. These trials with no fertilizer provide a basis for comparison, and would insure that any changes you see when you add fertilizer are in fact caused by the fertilizer and not something else.

However, not every experiment is like our fertilizer example. In another kind of experiment, many groups of trials are performed at different values of the independent variable. For example, if your question asks whether an electric motor turns faster if you increase the voltage, you might do an experimental group of three trials at 1.5 volts, another group of three trials at 2.0 volts, three trials at 2.5 volts, and so on. In such an experiment you are comparing the experimental groups to each other, rather than comparing them to a single control group. You must evaluate whether your experiment is more like the fertilizer example, which requires a special control group, or more like the motor example that does not.

Whether or not your experiment has a control group, remember that every experiment has a number of controlled variables. Controlled variables are those variables that we don't want to change while we conduct our experiment, and they must be the same in every trial and every group of trials. In our fertilizer example, we would want to make sure that every trial received the same amount of water, light, and warmth. Even though an experiment measuring the effect of voltage on the motor's speed of rotation may not have a control group, it still has controlled variables: the same motor is used for every trial and the load on the motor is kept the same.

A little advance preparation can ensure that your experiment will run smoothly and that you will not encounter any unexpected surprises at the last minute. You will need to prepare a detailed procedure for your experiment so you can ensure consistency from beginning to end. Think about it as writing a recipe for your experiment. This also makes it much easier for someone else to test your experiment if they are interested in seeing how you got your results.

Key Elements of the Procedure for an Experiment

- Description and size of all experimental and control groups, as applicable
- A step-by-step list of everything you must do to perform your experiment. Think about all the steps that you will need to go through to complete your experiment, and record exactly what will need to be done in each step.
- The procedure must tell how you will change your one and only independent variable and how you will measure that change
- The procedure must explain how you will measure the resulting change in the dependent variable or variables
- If applicable, the procedure should explain how the controlled variables will be maintained at a constant value
- The procedure should specify how many times you intend to repeat your experiment, so that you can verify that your results are reproducible.

Although your YSP mentor has already assigned you a space, you would usually need to also consider where you will conduct your experiment. You may need a lot of room for you experiment or you may not be able to move your experiment around from place to place. If you are working with human or animal subjects, you may need a location that is quiet. Scientists must think about these limitations before starting their experiments and find a location in advance that will meet their needs.

Your Assignment

Complete the “Grading Yourself” section of this lesson. Type your materials list and procedure on a Microsoft PowerPoint slide.

Materials List & Procedure

Grading Yourself

What Makes a Good Materials List?	For a Good Materials List, You Should Answer "Yes" to Every Question
Have you listed all necessary materials?	Yes / No
Have you described the materials in sufficient detail?	Yes / No

What Makes a Good Procedure?	For a Good Procedure, You Should Answer "Yes" to Every Question
Have you included a description and size for all experimental and control groups?	Yes / No
Have you included a step-by-step list of all procedures?	Yes / No
Have you described how to the change independent variable and how to measure that change?	Yes / No
Have you explained how to measure the resulting change in the dependent variable or variables?	Yes / No
Have you explained how the controlled variables will be maintained at a constant value?	Yes / No
Have you specified how many times you intend to repeat the experiment and are that number of repetitions sufficient to give you reliable data?	Yes / No
The ultimate test: Can another individual duplicate the experiment based on the procedure you have written?	Yes / No

Data Analysis & Graph

Take some time to carefully review all of the data you have collected from your experiment. Use charts and graphs to help you organize the data and patterns. Did you get the results you had expected? What did you find out from your experiment?

Really think about what you have discovered and use your data to help you explain why you think certain things happened.

Calculations and Summarizing Data

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

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

Graphs

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

Different types of graphs are appropriate for different experiments. These are just a few of the possible types of graph:

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

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

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

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

Generally, you should place your independent variable on the x-axis of your graph and the dependent variable on the y-axis.

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

Data Analysis & Graph

Your Assignment

Complete the "Grading Yourself" section of this lesson. Then, prepare your data analysis chart and plot graphs as appropriate in a spreadsheet program such as Microsoft Excel. Finally, import your information onto a Microsoft PowerPoint slide.

Grading Yourself

What Makes for a Good Data Analysis Chart?	For a Good Chart, You Should Answer "Yes" to Every Question
Is there sufficient data to know whether your hypothesis is correct?	Yes / No
Is your data accurate?	Yes / No
Have you summarized your data with an average, if appropriate?	Yes / No
Does your chart specify units of measurement for all data?	Yes / No
Have you verified that all calculations (if any) are correct?	Yes / No

What Makes for a Good Graph?	For a Good Graph, You Should Answer "Yes" to Every Question
Have you selected the appropriate graph type for the data you are displaying?	Yes / No
Does your graph have a title?	Yes / No
Have you placed the independent variable on the x-axis and the dependent variable on the y-axis?	Yes / No
Have you labeled the axes correctly and specified the units of measurement?	Yes / No
Does your graph have the proper scale (the appropriate high and low values on the axes)?	Yes / No
Is your data plotted correctly and clearly?	Yes / No

Conduct Your Experiment

Kayce Clemmons (2006); Photo taken by Damilola Coker

With your detailed procedure in hand, you are almost ready to start your experiment.

Before beginning, prepare a data table to help you collect your data. A data table will ensure that you are consistent in recording your data and will make it easier to analyze your results once you have finished your experiment.

Sample Data Table

Trial	**Faucet Opening (the Independent Variable)**	**Water Flow (the Dependent Variable)**
#1	1/4 open	[Write your data in this column as you make measurements during your experiment.]
#2	1/4 open	
#3	1/4 open	
#4	1/2 open	
#5	1/2 open	
#6	1/2 open	
#7	3/4 open	
#8	3/4 open	
#9	3/4 open	
#10	Fully open	
#11	Fully open	
#12	Fully open	

Note: Some experiments will require additional columns for two or more dependent variables.

It is also important to take very detailed notes as you conduct your experiments. In addition to your data, record your **observations** as you perform the experiment. Write down any problems that occur, ideas that come to mind, or interesting occurrences. Be on the lookout for the unexpected. Your observations will be useful when you analyze your data and draw conclusions.

We suggest that you get a **project notebook** so that all your information is kept in one place (don't use loose-leaf notebooks, you want to make sure all your information stays together). The data that you record

Conduct Your Experiment

now will be the basis for your research paper and your conclusions so capture everything in your **project notebook**, including successes, failures, and accidents.

If possible, take **pictures** along the way, these will later help you explain what you did and enhance your PowerPoint presentation.

Be as exact as possible about the way you conduct your experiment, especially in your measurements and note taking. Failures and mistakes are part of the learning process, so don't get discouraged if things do not go as planned the first time. You should have built enough time in your schedule to allow you to repeat your test a couple of times.

In fact, it's a good idea to do a quick **preliminary run** of your experiment. Show your preliminary data to your mentor or teacher, and make revisions to your procedure if necessary. Often there are glitches in the procedure that are not obvious until you actually perform your experiment--this is normal.

Your Assignment

Complete the "Grading Yourself" section of this lesson. Insert your data table into a PowerPoint slide. Have fun and be safe while conducting your experiment!

Grading Yourself

What Makes for a Good Experiment?	For a Good Experiment, You Should Answer "Yes" to Every Question
Are you collecting your data using a data table?	Yes / No
Are you taking detailed notes about your observations and recording them in your project notebook?	Yes / No
Are you being consistent, careful, and accurate when you take your measurements?	Yes / No
Are you being careful to insure that your controlled variables remain constant so as not to affect your results?	Yes / No
If you ran into any unexpected problems, have you adjusted your procedure accordingly?	Yes / No

Conclusions

Your conclusions summarize how your results support or contradict your original hypothesis:

- Summarize your results in a few sentences and use this summary to support your conclusion. Include key facts from your background research to help explain your results as needed.
- State whether you proved or disproved your hypothesis. (Engineering & programming projects should state whether they met their design criteria.)
- If appropriate, state the relationship between the independent and dependent variable.
- Summarize and evaluate your experimental procedure, making comments about its success and effectiveness.
- Suggest changes in the procedure (or design) and/or possibilities for further study.

If the results of your experiment did not support your hypothesis, don't change or manipulate your results to fit your original hypothesis, simply explain why things did not go as expected. If you think you need additional experimentation, describe what you think should happen next. Scientific research is an ongoing process, and by discovering that your hypothesis is not true, you have already made huge advances in your learning that will lead you to ask more questions that lead to new experiments. It does not matter whether you prove or disprove your hypothesis, but only how much you have learned from this experience.

Your Assignment

Complete the "Grading Yourself" section of this lesson. Type a summary of your results and conclusions into a Microsoft PowerPoint slide.

Grading Yourself

What Makes for Good Conclusions?	For Good Conclusions, You Should Answer "Yes" to Every Question
Do you summarize your results and use it to support the findings?	Yes / No
Do your conclusions state that you proved or disproved your hypothesis?	Yes / No
If appropriate, do you state the relationship between the independent and dependent variable?	Yes / No
Do you summarize and evaluate your experimental procedure, making comments about its success and effectiveness?	Yes / No
Do you suggest changes in the procedure and/or possibilities for further study?	Yes / No