Dear Teacher:

You tried.

In preparing your students for an upcoming science fair, you tried to explain the wonders of original experimentation: asking a question, forming a hypothesis, and designing an experiment — especially designing an experiment.

Then you asked your students to submit questions that would form the basis of their scientific inquiries. And what did you get?

Student: “I want to make a volcano.”

You: “Volcanoes are fascinating geological phenomena, Taylor, but your project must include the manipulation of an independent variable that causes a measurable response of the dependent variable. You need a hypothesis. You need to pose a question.”

Pause.

Student: “OK, my question is, ‘How do you make a volcano?’”

You tried.

Even the brightest kids can struggle with the process of scientific inquiry. This study guide — along with your local newspaper — can reinforce that process.

As your students gear up for a science fair, they can pull out the center section and refer to it while creating their projects. Even if your school doesn’t have a fair, you'll find this guide helpful in explaining the scientific method for solving all types of problems.

You’re the expert when it comes to science, of course, but don’t hesitate to enlist the help of your colleagues: Bring in a math teacher to discuss statistics; sign up an English teacher to give pointers on writing reports; ask the P.E. teacher to discuss exercise physiology; get the school (or district) nurse to serve as a consultant.

You might find it helpful to develop a classroom project to refer to throughout this unit. Depending on how much time is available, you can design a one-day physics trial or a two-week botany experiment.

Have fun with this guide, and perhaps it will inspire your students to start asking questions — and finding answers!

Go ahead: Give it a try!

Sources

Books:
The Parent’s Guide to Science Fairs by John Barron
Kidsource: Science Fair Handbook by Dana Voth
How to Excel in Science Competition by Melanie Jacobs Krieger
Students and Research: Practical Strategies for Science Classrooms and Competitions by Julia H. Cothron, Ronald N. Giese, and Richard J. Rezba
Science Fair Projects — Planning, Presenting, Succeeding by Robert Gardner
Science Fair Success Using the Internet by Marc Alan Ronser
Janice VanCleave’s Guide to the Best Science Fair Projects by Janice VanCleave

Web sites:
Synopsys Silicon Valley Science and Technology Championship
Kentucky-American Water Company Science Fair
Fayette County Public Schools
Kansas Science Olympiad
Intel International Science and Engineering Fair
Canada Wide Science Fair
Texas Science Olympiad
Lafayette College Libraries and Academic Information Resources

“Imagination is more important than knowledge. Knowledge is limited. Imagination encircles the world.”

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All's fair in love and war, as the saying goes, but that doesn't include science. In fact, a science fair might seem quite unfair. At the same event, you could see a project titled “Is Restructuring Amboliant DNA with Strecktides Effective?” right next to one titled “Our Friend the Beaver.” Unless that beaver can recite the Gettysburg Address, it's not a fair competition, is it?

It’s still a fair, though. In this case, the word means “an exhibition of educational displays.” And although most science fairs award prizes to the best projects, you're a winner just for participating.

By creating a scientific experiment, you can learn:

• more about something you’re really interested in.
• how to tackle a subject like a professional scientist would.
• how to organize a long-term project.
• ways to communicate in writing and in speech.
• new ways to measure, observe, and record information.
• how to solve problems.

When you learn how to solve science problems, you’ll also learn how to solve other problems: computer problems, people problems, health problems — there are plenty to choose from!

The Method of Science

The secret to all this problem-solving is using the scientific method: a step-by-step plan to figure out life’s questions — big and small. Whether your project involves complex cell structure or flat-tailed mammals, the process is the same:

1. Spell out a question you want to answer.
2. Make an educated guess.
3. Try out your guess.
4. Decide if your guess answers your question.

There are important things to know about each phase of the scientific method, especially in Part 3, when you design an experiment to test your guess. In this guide, we’ll cover the high points of each phase.

The scientific method is the foundation of many great experiments, inventions, discoveries — and science fair projects! There are other ways to solve problems, of course, and there are other ways to create a project for the science fair, but this is a great recipe for success.

And speaking of recipes, you’ll learn in this guide that the scientific method can be used for everyday activities — even cooking:

Let’s say you’re crazy about cookies, and you make them for bake sales and special occasions. You want to liven up your chocolate-chip cookies with nuts, but,

1. What kind of nut tastes best in chocolate-chip cookies — walnuts or pecans?
2. You’ve always thought that pecans are tasty.
3. You make a batch with walnuts and one with pecans, then get several people to taste one of each.
4. Eighty percent of those people preferred walnuts.

So, walnuts it is. That was it! That was the scientific method. You might not win a science fair with that experiment, but you might bake a better cookie.

Successful science fair projects require imagination, effort, and — most important — time.

As you’ll learn in this guide, pulling together a project involves much more than you might expect. The earlier you get started, the more time you’ll have to develop an idea, test it, write a report, and make a display for the fair.

If your school has a science fair in December, start planning your project in September. If your test (experiment) can be done in two weeks, plan on two months. Instead of taking two days to create your display, give it two weeks.

By planning your project months in advance, you’ll learn more and stress less.

Activity

Besides scientists, who else uses the scientific method to solve problems? Nearly everyone does! To investigate this idea, get into small groups, look through the newspaper, and make a list of careers and jobs you read about (be sure to check the employment ads). Beside each one, write how a person with that job might use the scientific method (even if they don’t call it that) to solve problems at work. Discuss as a class.

Activity

The Federal Bureau of Investigation often uses science — and the scientific method — to solve crimes. Find a news story about a murder, theft, or robbery and write a paragraph about how an FBI agent or police officer would use the scientific method to solve a crime.

A Line from Einstein

“The only source of knowledge is experience.”
“I’ve got it!” she said. “My science project will be — no, that’ll never work. “Maybe I could — no, too expensive. “So what if I — no, that would take years. Well, but, no, so ...” “The title of my project for this year’s science fair,” she finally announced, “is ‘Our Friend the Beaver.’ ”

Finding a good topic for a science fair project can be a challenge — even a nightmare, maybe. But once the right idea hits you, it will play out in your mind like a dream.

To get to that point, start first with what is on your mind: What interests you? What troubles you? What is it that captures your imagination? What have you always wondered about? Pick a topic you really like; you’ll be spending a lot of time with it.

Now is the time to start a science logbook. If you don’t write down project ideas as soon as they come to you, they might slip away. Let’s take a step-by-step approach to forming ideas; be sure to write it all down in your logbook:

**Step 1.** List your favorite topics and activities, like stargazing or fishing. Don’t try to be scientific yet — just list hobbies, collections, sports, TV shows, books, animals, places, foods, machines, etc.

**Step 2.** Below each entry, write actions or behaviors related to that activity. For example, if you like to look at stars, you might say:
- Stars shine at night.
- We group stars into constellations.
- Stars are balls of burning gasses.

**Step 3.** Take stars for example, you might wonder: What time do stars shine brightest? Can you really see more stars on cold nights? How long do stars burn before they die out?

**Step 4.** Now it’s time to fine-tune your questions and ask how one thing affects another? Like this:
- How does time affect the brightness of stars?
- How does temperature affect the brightness of stars?

continued on page 5
continued from page 4

Step 5. After you’ve narrowed your list of topics to one or two areas, find out what others already know about those subjects. You’re doing an experiment to learn something, you know, so stay away from facts that everyone knows and dig a little deeper into a topic. Research will give basic information and serve as a launch pad for project ideas.

For example, if you are thinking about discovering the effect of temperature on water, a little research will tell you that water boils at 212 degrees F and freezes at 32 degrees F — not exactly great mysteries of science! So, be creative: Test the effect of altitude on the boiling point of water, or experiment to learn how different amounts of salt affect water’s freezing point.

You can draw on your own knowledge and experience to think of a topic that interests you, but to get serious about the topic, you’ll need to research it. Here’s a list of sources:

- **Encyclopedia**
- **Libraries:**
  - To get the most out of school and public libraries, here are a few research tips:
    - Before you go, ask your teacher how to make a bibliography (list of sources used). This information will help you — or another researcher — to find this source again.
    - The more recent the publication date, the more current the information.
    - Be sure you’ve got a library card to check out books with lots of useful information.
    - Take your logbook and write a summary of helpful magazine and newspaper articles — along with bibliographic information.
    - All libraries have a dictionary — be sure to use it when you run into new words.
- **The World Wide Web:**
  - It’s huge, and there’s more about it on page 14.

**Teachers**

**Parents and other family members**

**Experts:**

Scientists, doctors, engineers, and college professors who specialize in your project topic can answer questions and make suggestions. Check with local universities, museums, planetariums, and labs, or contact experts by writing them at their place of work.

Step 6. Your big question should focus on things you can measure. Let’s take the questions from Step 4 and look for specific ways to measure the effect of one thing on another:

- How does the amount of moonlight affect the number of stars we can see?
- How does air temperature affect the number of stars we can see?

As you can see, we’ve taken the broad categories of stargazing and fishing and created narrow questions with measurable results. The more specific your question is, the easier it will be to set up a successful experiment.

Step 7. Let’s do a reality check here. We’ll need to toss out ideas if they require sophisticated equipment that we can’t get. For example, to measure the amount of moonlight, we’d need a photometer. Of course, if your uncle happens to work in a photo lab, you might keep the moonlight question as a possible topic.

Toss other topics that would take too long or cost too much.
Once you have a question in mind — and in your logbook — it’s time to start looking for answers. On page 3, we talked about the four parts of the scientific method. The first is coming up with a specific question, and as you just learned, that’s quite a challenge!

Next on the list is making an educated guess, also called a hypothesis. It’s from the Greek words meaning “to place under,” and a hypothesis is just that: A foundation, or basis, for investigating something.

A hypothesis isn’t a fact, but a prediction of what you think will happen. Your prediction is based on your research; remember that a hypothesis is an educated guess.

Let’s Get Technical

One of the benefits of performing an experiment is learning how to think and act like a scientist, even if your project isn’t highly technical or complicated.

To make your project sound scientific, you should crank up your vocabulary a notch or two. Before you turn your question into a hypothesis, replace everyday words with language that’s more scientific:

<table>
<thead>
<tr>
<th>EVERYDAY</th>
<th>SCIENTIFIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>sprouting</td>
<td>germination</td>
</tr>
<tr>
<td>things</td>
<td>factors or variables</td>
</tr>
<tr>
<td>remembering</td>
<td>memory retention</td>
</tr>
<tr>
<td>changes</td>
<td>fluctuations</td>
</tr>
<tr>
<td>lightning bug light</td>
<td>bioluminescence</td>
</tr>
</tbody>
</table>

You can get scientific phrases from science magazines, books, scientists, or your teacher. Your goal here is to use the same terms that other scientists use.

Predict the Future

In a scientific experiment, you’ll change one thing, or variable, then observe and record how that affects another variable. In your hypothesis — stated before the experiment — you go out on a limb and try to predict the results of your experiment.

There’s no shame if your results turn out different than you predicted. After all, finding out what doesn’t work — disproving your hypothesis, or guessing wrong — gets you that much closer to learning what does work.

You’ll learn more about variables on pages 12 and 13.

A Big ‘If’

You can word your hypothesis so that someone who knows nothing about your project can understand the problem and your prediction all at once. Often, it is best to phrase your hypothesis using an “if/then” statement:

- If the sun comes up in the morning, then the air temperature will increase.
- If enough weight is added to a canoe, then it will sink.
- If basketball players wear high-top shoes, then they will have fewer ankle injuries.
- If mice are rewarded for navigating a maze, then they will learn faster.

In some cases, using an “if ... then ...” statement will be awkward. Change the wording if you need to, but don’t change the idea of the “if/then” hypothesis: If I change one variable (changeable thing), then another variable will change and I can measure the results.

Activity

Change the wording of five newspaper headlines to make them sound more scientific or technical. This shouldn’t be too difficult, because journalists often use short, simple words to make headlines fit into the available space. Share your revisions with the rest of the class.

Activity

Get into small groups and read letters to the editor and opinion columns in the newspaper. When a writer suggests a solution to a problem, write it as an “if/then” statement. Compare your group’s statements to those written by other groups.

Activity

With a hypothesis, a scientist predicts what she believes will happen. Read three news stories and then form a hypothesis for each. Make sure you are predicting how one factor (variable) will change another. Example: If the drought continues, local farmers will produce fewer tomatoes than average.

A Line from Einstein

“The whole of science is nothing more than a refinement of everyday thinking.”
science fairs are like beauty pageants. OK, there are no swimsuit competitions, but the events have a similar structure. Both have local competitions open to everyone, and the winners advance to larger events.

The beauty of a science fair is the chance to answer questions and solve problems. You’ll see several questions on this page, but they are just suggestions. Your project will be most rewarding if you tackle a question in an area you love: sports, nature, the earth — you name it!

If the top beauty pageant is Miss America, Miss USA, or Miss Universe, the top science fair in the United States is the Intel International Science and Engineering Fair. Canada, too, has a national event: the Canada Wide Science Fair.

Just as some beauty pageants have a talent portion and some don’t, different science fairs have different guidelines. Before you spend much time thinking about an idea for your project, make sure you know the rules of the fair you’re entering. It would be a shame to research and design an experiment to see if carbohydrate intake has an effect on athletic performance — only to find out that your science fair prohibits using human subjects.

Another reason to check the rules of the fair is to find out what the project categories are. The Intel International Science and Engineering Fair, for example, has the following categories:

**Behavioral and Social Sciences**
- Biochemistry
- Botany
- Chemistry
- Computer Science
- Earth and Space Sciences
- Engineering
- Environmental Science
- Gerontology
- Mathematics
- Medicine and Health
- Microbiology
- Physics
- Zoology
- Team Projects

In small groups, think of a three-letter abbreviation for each science fair category listed above. Then, go through the newspaper and label every news story, ad, cartoon, etc., according to which science fair category it mentions or involves. There could be several categories for one item.
Write It Up!

Whether your science fair project was wildly successful or mildly disappointing, you’ll need to prepare a report. All the big-time scientists write up their experiments and so will you! This will give you a chance to sum up your experience as a scientist, and it will give others a chance to learn from you, as well as to evaluate your hard work.

Your logbook will be worth its weight in gold when you sit down to write, because your notes, observations, and measurements will be the backbone of your report. Use a computer — if at all possible — to make your report neater and easier to read. Each teacher or science fair might require a different format, but here are the most common elements of a science project report:

Title page: This should include the name of the science fair, the date, and your name. Let’s see, what else? Oh, the title! It should be in big letters, centered at the top of the page. The title should give readers a good idea of the question your project is intended to answer. Make it catchy.

Table of contents: Save this page until the whole report is written and all the pages are numbered, beginning with the abstract.

Abstract: This is nothing more than a summary of your project, but using “abstract” sounds cooler. Readers should be able to read your abstract and know the question you investigated, your hypothesis, how you tested it, and the results. Keep it brief.

Review of the literature: In this section, present the question that got you started on this project and then sum up what you learned in your research. Explain what other scientists have written about the topic and where you found the information.

Hypothesis: It might be repetitive, but your teacher might want you to state your hypothesis in a separate section.

Procedure: Keep one thing in mind here: Anybody who reads this section should be able to do your experiment exactly like you did. You’ll need to include detailed descriptions of the materials you used and a step-by-step explanation of how you set up your experiment, conducted it, and measured the results. Make sure you include the number of subjects in the experiment and the number of trials, or repetitions. This is also a good place to describe the variables of your experiment — independent (the thing that changes) and dependent (the measurable result of that change) — and your control group.

Results: List here all the facts and figures you obtained from your experiment — graphs, tables, photos, drawings, etc. — as well as a summary of the results and any problems you encountered.

Conclusion: Start out by restating your hypothesis (once more for old times’ sake!) and whether your data support it. This section should also include your explanation of any patterns you observed, suggestions for improving the experiment, and how the results might apply to other areas.

Bibliography: This section is a list of all the books, magazines, and articles you read, as well as the names of people you interviewed. Check with your teacher or contest rules for the format of this section.

For Display Purposes

Your display is not the most important piece of the science fair puzzle, but if people at the fair can’t read or understand your display, they won’t know what a great scientist you are. Even if you haven’t unlocked one of science’s great secrets, you still want to put your best foot forward at the science fair. Your display or exhibit, should be inviting, neat, and informative.

Build a backboard

Every science fair has rules governing the size of your exhibit, but a typical project will be displayed on a backboard (see diagram). You can buy a ready-to-use board or make your own.

Use two panels (let’s say 2 feet wide and 3 feet high) of a sturdy material — heavy cardboard, wood, or pegboard — and cut one to make two “wings,” each 1 foot wide. Then use strong tape or hinges to connect the wings to the larger piece. Your backboard should be able to stand up without additional support. Use contact paper or cloth to cover the backboard if you wish.

Here are other parts of a display that you might be required to include. Whenever possible, print out all or part of the section of your report that contains information for your display:

1. Title: The title of your project should be short and catchy, in letters large enough to be read from several feet away. Use self-sticking letters (for the title and for other headings) or use a computer and print onto colored paper. Be sure to use a font that’s easy to read. The title should be at the top of the center panel.

2. Problem: This sheet should include the problem you hoped to answer and a brief review of the literature.

3. Hypothesis: If your hypothesis can be stated in one sentence, enlarge the size of the font to make the statement stand out.

4. Materials: List everything you used in your experiment, and be specific. For example, if you grew plants from seeds, explain what type of seed and what size pot you used.

5. Procedure: Visitors and judges at the science fair will read this section to find out what you did. Make it interesting, and remember that not everybody is as familiar with your topic as you are, so use terms and descriptions that will be easily understood.

6. Data: This section should be a visual explanation — graphs, charts, photos, etc. — of what happened. Ask your science or math teacher which type of graph will best display your data so visitors can quickly understand the results of your experiment.

7. Results: Here, you give a summary of the results using words instead of charts or graphs.

8. Conclusion: At the beginning of this section, state whether your hypothesis was proven or not, along with any other information you gathered from the experiment.

9. Next Time: Here, explain what you would do to improve your experiment or suggest related areas you’d like to explore. (Complete this section even if you know there will never be a next time!)

10. No Wasted Space! The area in front of your backboard should never be empty! Use it to display your logbook (which should be full of ideas, notes, observations, and measurements). This is also a good place for a model, photo book, any equipment you used, and a copy of your report.
Not every science fair is judged the same (who did put the fair in science fair?). It's safe to say, though, that every fair has a set of criteria — items to be scored — that students can read before beginning a project. While it's fun and you learn a lot simply by entering a science fair, you might as well play to win.

Below is a list of items that you might see on a judge's scoring sheet. Each could be checked off or perhaps scored as “below expectations,” “meets expectations,” or “exceeds expectations.”

**Topic**

- The topic is an experiment, not a demonstration.
- The topic shows creativity.
- The question is narrow enough to be tested.

**Hypothesis and variables**

- The hypothesis is clear and concise.
- The hypothesis identifies both dependent and independent variables.
- Other possible variables are held constant.

**Experimental design**

- The project includes an experimental group and a control group.
- The independent variable is clearly measurable.
- The project shows an imaginative use of materials.
- Data collection includes written observations.
- Data collection includes numeric measurements.
- The procedure is well organized and follows a logical sequence.
- Repeated trials are included and adequate.
- The number of subjects is included and adequate.

**Results and conclusion**

- Data is discussed and interpreted.
- Any errors in design or performance are included.
- The hypothesis is evaluated according to the data.

**Exhibit**

- The exhibit contains all of the required documents and sections.
- The exhibit is visually appealing.
- Charts, tables, etc., are used to show results.
- Project appears to be student's own work.

**Discussion**

- Student shows a clear understanding of the project.
- Conclusions are justified based on experimental data.
- The student identifies new questions for investigation, based on this project.
- The student discusses possible applications of the project results.

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**Better**

- Lay out all parts of the display before you glue or tack anything down.
- Avoid clutter.
- Use a tablecloth that looks good with your backboard.
  (Spread it on the table before you set up the board.)
- Make the display neat, colorful, and attractive.
- Stay close to your exhibit.
- Don’t eat or drink while you’re “on the job.”
- Bring a repair kit in case your display gets nervous and falls apart: tape, glue, extra paper, scissors, pens, etc.
- Use colored paper for each report section of your display, or print onto white paper and attach it to a colored background.

**Better Not**

Certain items cannot be used in your display; check the rules. These items are commonly prohibited because they can be harmful or messy:

- Live animals
- Liquids
- Animal or human tissue (Hair, teeth, and dried animal bones are usually allowed.)
- Harmful chemicals
- Combustible materials
- Flames
- Aerosol cans
- Poisons
- Drugs
- Sharp items (knives, needles, etc.)
Go with the Flow

- **Hmmmmmmmmmm**
  Start thinking about a science fair project months before the fair.

- **Idea factory**
  Gather ideas from teachers, books, this guide, parents, your yard, your room, your lunch, etc.

- **I’ve got it!**
  Write down your idea in your logbook.

- **Initial research**
  Find out if your idea is workable and how best to test it.

- **Too hard? Too simple? Just a plain bad idea?**
  You need a new idea.

- **Go on – ask!**
  Pose your topic as a question to be answered.

- **Hypothesize**
  Answer your question by predicting the outcome of an experiment.

- **Design an experiment**
  Stay focused on answering the question.

- **Is your question untestable?**
  Try asking a different question. You might even need a new idea.

- **Let the experiment begin**
  Be alert, observant, and safe.

- **Take notes**
  Write down everything that happens and measure whatever can be measured.

- **There you have it**
  Analyze the results, draw conclusions, and check your results against your hypothesis.

- **Write it up**
  Write a report of your experiment from start to finish.

- **Create the display**
  Prepare a backboard and pack up any apparatus or models you want to exhibit.

See you at the fair!
More Projects

Original, scientific experiments are the only type of projects allowed at some science fairs, but they’re not the only type of science projects. For students with a strong interest in math, computer science, engineering, or the social sciences, other projects might be more stimulating.

Let’s take a look at the world of non-experimental projects. Before you get too excited about any of them, check with your teacher to see if your school or local science fair will accept one of these projects:

Show and Tell

There have probably been more volcanic eruptions at science fairs than from within the earth’s crust. This type of project is a working model — one that shows a scientific principle and looks cool while doing it. Pinhole cameras, security alarms, telescopes, and generators are also popular demonstration projects at science fairs.

Plain models, too, are an effective way to present information about interesting topics. A student who constructs a three-dimensional model of an eyeball, heart, or the solar system can explain how each works.

Another type of show-and-tell project is a display. This could be a collection of seashells, fossils, bird nests, or wildflowers, along with information about the topic and each item.

These projects do not involve a hypothesis and experimental design. Still, you have to learn about an item before you can build or display it. If you choose a show-and-tell project, be creative. Include little-known facts, life cycles, photographs, or historical research in your presentation.

Research Paper

Most science fairs require participants to write a report to go along with their experiment. In some cases, a report — or a research paper — can be a project all by itself. As with show-and-tell projects, a report does not require a hypothesis. Instead, a student thoroughly researches a topic — how salt is removed from seawater or the history of space exploration, for example — and presents his findings along with photos and other illustrations.

I’m Conducting a Survey

Your project question might be about how people behave or what they think — something that can’t be answered in a science lab. If that’s the case, the best measuring instrument might be a survey, a set of detailed questions.

Surveys are frequently used in the social sciences, such as psychology or sociology, but not in the “hard” sciences — physics, chemistry, and biology, for example. As a result, some science fairs allow surveys and others do not.

If you look on page 12 at the steps of an experiment-based project, you will see that a survey-based project can fit that formula. Instead of designing an experiment, though, you must design a survey that provides clear and meaning-ful results. The questions you ask must be phrased with the same care you would take in a laboratory.

Just as you would test the apparatus of an experiment, you should also test survey questions before you collect data. Make sure you have a large sample (survey a lot of people). Also, be sure to protect the identity of the people involved and ask a teacher or other professional to approve your survey in advance.

Brand X or Brand Z?

A product comparison is another type of project that has many ingredients in common with a science project, but is often not allowed in science fairs.

On the plus side, you can be very scientific in determining which paper towel is stronger or which type of popcorn pops the most kernels, but your ability to test a hypothesis is limited. Even though you change one variable (brand of paper towel) and measure the results (amount of weight supported by each towel), it’s tough to develop a scientific hypothesis without knowing more about the products.

Contact the manufacturers of the products you’re testing and politely request information about the products’ composition, or ingredients. For example, if you know that Popcorn X contains a type of oil that heats faster than the oil in Popcorn Z, you’ll have a basis for scientific study. You might hypothesize that X will pop better, and then test both.
Chances are, you’ve done an experiment in a science class: You walked in, everything was already set up, and the teacher told you what to do. What makes a science fair fun is you get to design your own experiment. You’ll have to think it through and follow through: Successful science experiments rely on realistic expectations, careful planning, and detailed execution.

Start with Variables

As we discussed on page 6, a scientific experiment is testing the effect of one thing on another. Selecting which variables to include in the experiment can take you from very broad subjects, like electricity, plants, or bugs, to very specific questions:

☛ How does the diameter of copper wire affect its conductivity?
☛ How does nitrogen fertilizer affect the growth of grass?
☛ How does pepper affect the chirping rate of crickets?

The independent variable is the one that you change or manipulate (the size of the wire, the amount of nitrogen, or the amount of pepper). The dependent variable is affected by those changes, and you’ll need to be able to measure that effect (the power of the current; the height, width, and number of grass plants; or the number of chirps per minute).

All other variables must remain the same, or constant, in an experiment. That way, you can be sure that any change is a result of something brought about. For example, if you’re testing the effect of rainfall (the independent variable) on the growth of corn (dependent variable), make sure the soil, type of corn seed, and amount of sunlight remain constant.

It might be interesting to know how soil type affects corn, or how different amounts of water and sunlight affect growth, but those are separate experiments. Keep everything the same except the variable you’re testing.

It’s vital that you understand how to develop variables. For practice, look at the items below and write under “Independent” something that can be changed in an experiment. Under “Dependent,” write something that can be affected and measured by that change.

<table>
<thead>
<tr>
<th>Item</th>
<th>Independent</th>
<th>Dependent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bean plant</td>
<td>hours of sunlight</td>
<td>height of plant</td>
</tr>
<tr>
<td>Glue</td>
<td>________________</td>
<td>______________</td>
</tr>
<tr>
<td>Mildew</td>
<td>________________</td>
<td>______________</td>
</tr>
<tr>
<td>Weed killer</td>
<td>________________</td>
<td>______________</td>
</tr>
<tr>
<td>Human hair</td>
<td>________________</td>
<td>______________</td>
</tr>
</tbody>
</table>

By the way, don’t mistake this list for a recipe.

Under Control

In the case of the corn experiment, the group of plants that receives different amounts of water is called the experimental group. In a control group, all variables — including the independent variable — are held constant. This will let you compare the results of your experimental group with what would happen under “normal” conditions.

Activity

In small groups, read four newspaper stories about people (in politics, business, athletics, etc.) who are trying to change something (a social problem, slumping sales, or a losing streak, for example). For each story, write down an independent variable (something that is being changed) and the dependent variable (the result of that change). Share your variables with the rest of the class, and discuss these questions: Is there a control group? What things remain constant? Are there are other independent variables at work?
The Element of Design

This is it, baby: experimental design. The uphill road of the scientific experiment reaches its peak here and starts rolling down. If the design is right, it’s a smooth run. If it’s flawed, the wheels fall off and you start over.

If the wheels do come off, you’ll be glad you took good notes. By checking your logbook, you can reconstruct your project up to the point where things went wrong. You won’t have to reinvent the wheel, so to speak. Be sure your logbook includes these steps:

1. **State your purpose.** It might seem hard to believe, but as you get deeper into a subject, you can lose sight of what you set out to do. A brief statement detailing what you want to learn — or what problem you hope to solve — can keep you on track.

2. **Plan a schedule.** It might change. Heck, it will change, but the act of writing a plan will be an exercise in organization. You’ll also get an idea of just how early you need to start your project.

3. **Spell it out.** State your hypothesis, dependent variable, and independent variable. Some science fairs require that you also identify the constants, number of subjects in the experimental and control groups, and number of repetitions, or trials.

4. **Make a list.** Write down each piece of equipment and be specific about where you plan to get everything, the size, and number needed. Also describe where you will assemble and store the apparatus, or equipment.

5. **Put it all together.** Write a detailed procedure, or description, for assembling and conducting your experiment. This will serve as a set of instructions for when you conduct and repeat the experiment. Anyone should be able to read your procedure and recreate your experiment.

6. **Just do it.** Conduct your experiment as you planned it, and take notes on everything that happens, not just what you expect to happen. As Isaac Asimov said, “The most exciting phrase to hear in science, the one that heralds the most discoveries, is not ‘Eureka!’ (I found it!), but ‘That’s funny …’”

7. **Collect the data.** Record in your logbook the changes in the independent variable. If you plan to track a change over time, make a chart; if you record data from several trials, set up a table. Write down qualitative changes (color, smell, appearance, etc.) as well as quantitative changes, those that are measured by tools.

8. **Analyze the data.** Check with your science — or math — teacher to determine the best way to change raw data, the measurements you jot down, into useful information using statistical methods (mean, median, percent change, significance, etc.)

9. **Form a conclusion.** Look back at your hypothesis, decide if the data supports or rejects it, and say so. No matter what happens in your experiment, you must link the results back to your hypothesis.

10. **Take a deep breath** — your experiment is over. You still have to write up and display these steps, but the most difficult part is past.

Safety First

**Don’t experiment with your own safety.** Make sure you:

- Work under the supervision of an adult.
- Use all instruments and equipment correctly.
- Wear goggles and protective clothing when working with chemicals and other dangerous materials.
- Treat all chemicals and fumes with caution.
- Keep clear of danger from electrical current and devices.
- Take care not to burn yourself or your clothes when working with an open flame.
- Watch out for sharp, hot, or broken glass.

Nobody’s Perfect

Things can go wrong with a science project, just as they can — and do — in everyday life:

- Your dog, the same one that ate your homework that time, dug up your control group.
- The leaves dropped off before you got a chance to examine them.
- The batteries leaked.
- You couldn’t find any fossils.
- Your hypothesis was wrong.

Hey, wait a minute, that last statement isn’t a problem. Rejecting a hypothesis isn’t a mistake. These are mistakes:

- ignoring facts to achieve the hypothesis.
- not making accurate measurements.
- running only one trial. Do at least three trials to balance out any weird results.
- not testing equipment.
- testing too few subjects. Otherwise, one abnormal subject can throw off the results.
- not allowing enough time.

Whether the mistakes are a result of flaws in the experimental design or bad luck, most can be eliminated by planning well.

**Activity**

Taking photographs of your project before, during, and after the experiment can help others understand what happened. Pictures can also help explain any problems or surprising results. Pick out five photos in the newspaper and write down four facts about each that are not included in the caption but can be seen in the photo. As a class, discuss how photos expand your understanding of a person or event and how they also provide important information.

**Activity**

In small groups, find a news story in which someone is trying to change something: disease, poverty, quality of life, etc. Identify the person’s hypothesis, independent variable, and dependent variable. In other words, write up a real-life event as if it were a science project. Share your “project” with the rest of the class.

**Activity**

Read the letters to the editor. If a writer is suggesting a change to solve a problem, what is her hypothesis? Can you find any flaws in her “experimental design?”

**A Line from Einstein**

“Not everything that counts can be counted, and not everything that can be counted counts.”
A century ago, it took weeks or months for news about scientific breakthroughs to spread across the United States. Today, that information is available at the click of a button — or a mouse.

The Internet and the World Wide Web are great tools for inspiration and research once you become familiar with using search engines and electronic mail. If you’re not, ask your librarian or teacher for help.

Whether you have experience in Web-based research or this is your first time online, use good judgment:

- Make sure your computer is equipped with virus protection software before you download files.
- Never supply information such as your Social Security number or a credit card number without permission from your parent.
- Just use your first name, and don’t give your telephone number or address to anyone.
- Not all Web sites are reliable and up to date. You can be more confident about information from a government or university Web site, for example, than from someone’s personal site.

If you are unable to find answers to all your questions, use the Web to contact experts — teachers or other professionals — in the field. Be polite and specific in your question or your request for information and allow plenty of time for the expert to respond; don’t wait until the last minute to ask your question.

Following are URLs, or Internet addresses, of Web sites that focus on science fairs or topics. Of course, one good site often leads to another. If you are using a home computer, bookmark the sites you plan to visit again. Otherwise, jot down the Web address of useful sites in your logbook.

GENERAL INFO AND PROJECT IDEAS
Intel International Science and Engineering Fair
http://www.sciserv.org/isef/

Science Fairs Home Page
http://www.stemnet.nf.ca/~jbarron/scifair.html

Dr. Internet’s Science Projects
http://www.ipl.org/youth/DrInternet/experiment.main.html

Science Fairs and Science Projects
http://www.gallaudet.edu/~mssdsci/scifairs.html

The Internet Public Library
http://www.ipl.org/youth/projectguide/

WEB SITES AND BIBLIOGRAPHIES
When you make a bibliography (list of references), it’s easy to find information about the books and magazines you used. But finding that information about a Web site is tricky. Here’s the order of what you should list:
1. Author: Check the top and bottom of the document, but don’t list the Web master’s name.
2. Title: Look at the top of the page or at the title bar on the browser’s window.
3. Date of publication: Look at the bottom of the page to find when the document was created or last updated. If you can’t find a date, use “n.d.” (no date).
4. Date accessed: Also list the date you looked at the document; it will often appear in the bottom right corner of a printout.
5. URL: The URL, or Web address, appears near the top of the screen in a box and, on some printouts, in the upper right hand corner.

Unless you get other instructions, your Web page citation should look like this:
Many newspapers have Web sites where you can find scientific information. Visit as many newspaper Web sites as you can and decide which one has the best site for science projects. Write a paragraph explaining your choice, along with the things that make a newspaper site “science-friendly.” To find most U.S. and Canadian newspapers, go to Metagrid: Newspapers and Magazines at http://www.metagrid.com/news/canada_usa/.

Write down a step-by-step process for researching science information on the Web. Write it so that anyone could follow your instructions and get the same results (like the procedure of an experiment).