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Gateway to Discovery:

A Science Fair Guide to Get You Started

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It starts with curiosity. Why does something act the way it does? What would happen if…? Such questions form the basis of scientific inquiry, and you probably ask them all the time! A science fair project provides the opportunity for you to act on your questions and discover answers. As you formulate a question, develop a hypothesis, design an experiment, and analyze the results, you'll gain valuable critical thinking skills. As you design a presentation and interact with judges, you'll grow in confidence and public speaking ability. In fact, science is just one of many subjects used in designing a science fair project—you also learn research, writing, grammar, planning and organizing, math, logic, and more.

Science fairs are a wonderful way to get excited about learning, but they require a lot of hard work. If you want the benefits of participating in a science fair, but don't know where to start, this guide is for you. It will provide a brief overview of the most important aspects of a science fair project and get you well on your way to having a display at your local fair. Though the information is most applicable for middle school students, it can be adapted for use with elementary students and can be a great resource for first-time high school participants.

What's In the Guide

The Scientific Method

The key to a good science fair project is the **scientific method**, an essential tool for scientific discovery and sound conclusions. The scientific method acts as a tour guide through the world of inductive reasoning: it helps you test a specific phenomenon and draw a general conclusion from the test. It will help you keep your project well organized, and also help you avoid "jumping to conclusions." The method can be summarized in five simple steps:

- **Define the problem.** Ask a question you can answer through experimentation.
- **Observe/Gather data.** Collect information about the topic—learn as much as you can. Sometimes what you learn will cause you to rework your question.
- **Predict/Hypothesize.** Based on the information you found in your research, predict an answer to your problem (make a **hypothesis**). Tell *why* you predict a certain outcome.
- **Experiment.** Design an experiment to test your hypothesis.
- **Analyze data/Form conclusion.** Evaluate the results of your tests to determine if your hypothesis was correct. If it wasn't, explain why not.

That's the scientific method in the abstract. Now let's apply it to an example situation:

- **Define the problem.** I noticed something funny about my mom's houseplants. She had two that were exactly the same, but when my sister put one of them inside her fort it started to look a lot worse than the one by the window. I wonder why? Maybe it was the sunlight: *Does lack of sunlight affect plant growth?*
- **Observe/Gather data.** My science textbook says that plants use energy from the sun to make their food in a process called photosynthesis. Without any sunlight they couldn't make any food, and would die. But what about a plant that got just three hours less sunlight per day? Would it suffer? My refined problem: *Does a lack of sunlight for three hours during the day affect plant growth?*

- **Predict/Hypothesize.** Since sunlight is necessary for a plant to live, I predict that even three hours less sunlight per day will have a negative effect on plant growth.
- **Experiment.** I will test my hypothesis by covering some bean plants for three hours during the sunniest part of the day, then compare their health with plants that were left uncovered. There are many different factors that could affect plant growth (water, seeds, soil), but since I only want to test the effect of sunlight, I will control my **variables** carefully. Each bean seed will come from the same seed packet, and will be planted at the same depth in the same kind of soil. Each plant will receive exactly the same amount of water per day. Sometimes a factor beyond my control could affect the results, so to avoid basing my conclusions on a "fluke," I will use several plants. Three will receive full sunlight (these are the **control**); three will receive partial sunlight, and I will average the results.
- **Analyze data/Form conclusion.** Every day for three weeks I measure the height of each bean plant, the diameter of the stalk, and the breadth of the leaves. I also record the time of day the plants are covered and whether the day is sunny, partly cloudy, or cloudy. By looking at this data I can now determine if my hypothesis is correct and answer my original question. I can also suggest modifications to the experiment for further study (e.g., have three test subject groups: one that gets full sunlight, one that is covered for six hours, and one that is covered for three hours).

Choosing a Question

A science fair project can't get much better than its original question. Though the temptation to get right to experimenting is strong, it is better to spend significant time developing your topic first. Starting with a solid foundation—an interesting, specific, and testable question—will make building your project much easier.

Criteria. Try to focus on inquiry-type topics instead of demonstration-type topics. In other words, judges want to see students design an experiment to answer a question they have. They do *not* want to see a mere demonstration of a principle that is already common knowledge.

Good questions will meet several criteria: They will be

Questions to Ask:
- Can I do it safely?
- Do I have enough time?
- Can I control the variables?
- Can I measure the results?

- **Clear.** This means having **operational definitions**. Many questions will start with the words "what is the best…", but you need to define exactly what you mean by "best." In our plant growth example we need to have an operational definition for the "negative effects" of lack of sunlight: *I will operationally define "negative effects" as shorter stalks, smaller stalk diameters, and smaller leaves.*
- **Safe.** As with any science project, you must choose a topic you can safely investigate with the equipment you have. Be aware of the safety regulations at your science fair.
- **Quantifiable.** You should be able to arrive at an answer to your question through experimentation. Your experiment needs to have components that can be changed (or be observed to change, e.g., temperature) and measured. You should also be able to adequately control your variables.
- **Interesting!** You must be interested in your topic, or you will have a hard time finding motivation to work on it. Ask a question that you really want to answer, and you will enjoy the investigation process and put together a good presentation.

Brainstorming. Finding a topic that meets all of these criteria is not always easy! The best place to start is with your interests. Do you like animals? Electricity? Astronomy? Have you seen things in your backyard or in your house that have caused you to wonder? Have you done a science experiment in school that you really liked? Maybe you could design a similar experiment to discover something new about the topic.

You can also look for ideas in science magazines, science news websites, or guides like this one. Many books about science fairs will have lists of key words and categories that will help you start thinking in the right direction. Some books even have project ideas, but if you find one you like, try to "make it your own" by looking at the topic from a different angle or testing for another variable. When something excites your interest, write it down. It is a good idea to start keeping a science fair ideas notebook several months in advance.

Research. Once you have found a topic that interests you, begin your research. Younger students can look in books, magazines, and on the internet (you are more likely to get accurate information from university or government websites). Older students can gain access to a local university or college library to find scientific journals. It is also a good idea to write letters to government departments or people with expertise in the area you're studying. (A personal interview is even better, if you have the opportunity.) They can often give you important information or at least point you in the right direction. You may also consider finding a mentor in the appropriate field who will advise you throughout your investigation. Some science fairs have mentor programs to match you up with a scientist who knows your topic. (You will have to submit an application for this program.)

Wherever you get information, be sure to write down the source in a project notebook. When you write your science report you will need to give credit to your sources, and you don't want to take the time to find them all again!

Restrictions. Each science fair has a set of guidelines that include restrictions on certain topics. Be aware of these restrictions as you choose your topic. Many science fairs are affiliated with the Intel International Science and Engineering Fair (ISEF). ISEF has strict rules regarding the use of human and animal subjects and potentially hazardous substances. Even if your local fair has more lenient rules, you need to be familiar with the ISEF rules as well. You don't want to win your state fair and then be disqualified from higher competition for not complying with the higher competition's regulations! Find the ISEF rules and guidelines here.

Check Restrictions for:
- Human subjects
- Vertebrate animals
- Potentially hazardous biological agents
- Controlled substances
- Hazardous substances or devices

Developing the Experiment

After you have chosen a question and made a hypothesis, it is time to develop your experiment. This will be easier if your question is specific and quantifiable, but there are several areas you will need to think through carefully.

Variables. Whenever you test a hypothesis, you should identify all the factors—variables—that could have an effect on your results. Only test the effect of one factor at a time; all the other variables must be kept constant. There are three categories of variables:

- **Independent.** An independent variable is your changing variable. You control the change. In our plant example, you control how many hours of sunlight each plant gets.
- **Dependent.** The dependent variable is the measurable result of the change of your independent variable. If you change the number of hours of sunlight a plant gets (independent), you will measure the resulting growth of the plant (dependent).
- **Controlled.** These are the variables you keep constant, so they cannot affect your result. For example, give each plant exactly the same amount of water and plant the seeds at the same depth in the same type of soil.

Independent:
Hours of sunlight

Dependent:
Growth of bean plant

Controlled:
Water, soil, seeds, planting depth, etc.

Protocols. Your goal as you design your experiment is to come up with a procedure that someone else could repeat and get the same results you do. To make sure your procedure is repeatable, you need to come up with a list of guidelines for conducting the experiment; these are called protocols. There are two categories of protocols: one contains rules for following the procedure under normal conditions; the other contains rules for what to do in unusual circumstances. For our bean plant example, the first set of rules may tell you how much water to give the plants, how deep to plant the seed, etc. The second set of rules would outline what to do if one of the plants is tipped over (e.g., make sure it is refilled with soil up to the same level as before).

Multiple tests. If you perform your experiment only once, or if you use only one test subject (e.g., one bean plant), you might get some faulty results. Even if your result seems to confirm your hypothesis, you can't be sure some other variable didn't have a hand in the outcome. (What if the growth of your bean plant was stunted by a parasite attack on the roots instead of by lack of sunlight, for example?) Scientists test their hypotheses over and over again, and for your science fair project you should too! The more you test, the more accurate your results will be. If you get the same results each time, that will go a long way to confirming your hypothesis. Make sure you follow the exact same procedure each time you do a test.

Records. Take careful notes of your procedures and all your observations and measurements. You may also want to make sketches or take pictures at various stages of your experiment. You can use these notes for you presentation at the fair, so be neat and organized!

Analyzing Data & Forming a Conclusion

After you have finished your experiment and gathered all your data, you're ready to formulate your analysis and conclusion. There are three important parts to your analysis (younger students may only need to include a conclusion):

- **Conclusion.** Did your results support your hypothesis? How? (Be specific!) If your results did *not* support your hypothesis, this doesn't mean you failed! In fact, it gives you valuable information and can lead you to ideas for further experimentation. Make sure that you describe *how* your results contradicted your hypothesis.
- **Error Analysis.** There are often variables beyond your control that might have affected your results. It is important to identify these variables in your analysis so that someone looking at your data will know the possibility of inaccuracy. For example, you should note if your uncovered plants got less light energy because half the days were very cloudy.
- **Limitations.** In this part of your analysis, you caution against over-generalizing your results. For example, you may have proved the negative effects of less sunlight on a bean plant, but you cannot take your conclusion and apply it to any other type of plant. One of the limitations of your study is that you only tested one kind of plant.

After you have written your analysis, you may also want to include some ideas for taking your investigation further. Some students work on the same topic for several years, continually building on their findings from the year before. Even if you don't intend to continue your project, you can impress the judges by thinking about the direction it could go.

Presenting your Project

Last, but *not* least, you need to get your project ready for presentation at the fair. Judges have a lot of projects to look at, and their time is limited, so your display should be well-organized and easy-to-follow. You may have a fantastic experiment and come up with amazing results, but if you present it poorly, a judge may not take enough time to see the quality of your investigative work. Do your project justice by taking time to present it well! There are several important components to your presentation:

Abstract. It may seem like no big deal to write a 250-word summary of your project, but your abstract may be the key to your success at a fair. Many judges read abstracts ahead of time to get an idea of the different projects, so their first impression of your work will most likely be based on your abstract. An abstract should be no more than 250 words and should include a brief synopsis of the following:

- Purpose of experiment
- Procedures used
- Observations/Data/Results
- Conclusions

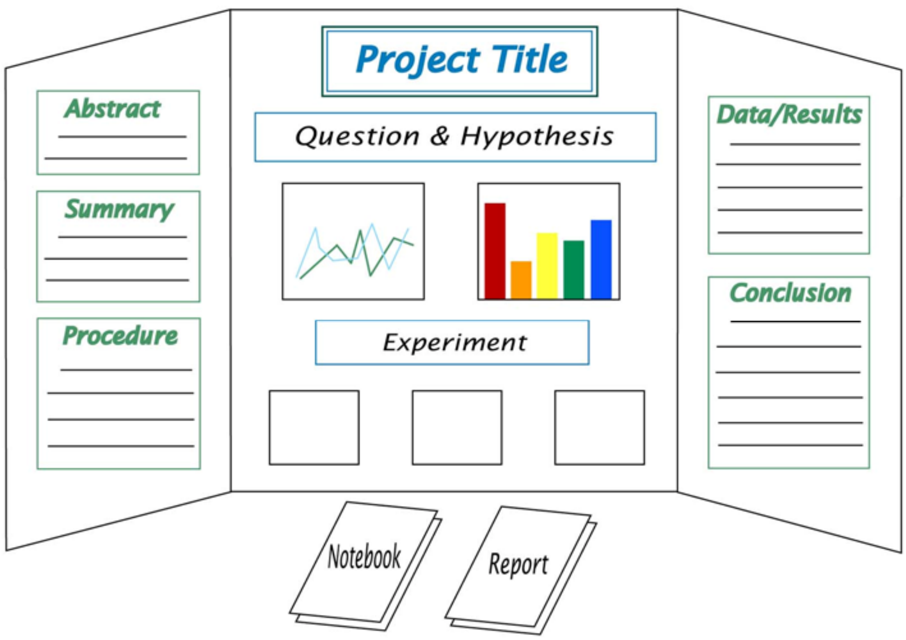
The abstract should be written in sentence style, not list style, so you may alternate back and forth between the four categories above, especially if your project has several levels of investigation. To see a sample upper-level abstract, visit the ISEF website.

Spend time working on your abstract—make it capture the judges' attention and convince them that you have done some serious work.

Science Report. Reports are not always required for younger grades, but for 6th grade and up you will usually have to write one. The report is a detailed explanation of your entire project—background information (with proper citation of sources), purpose, procedures, data, conclusions, etc. Don't be overwhelmed! If you took good notes during your researching and experimenting stages, you have all you need to write a great report. You can also include your graphs and pictures in the report to support your text. Display your report in a three-ring binder on your table at the fair.

Science Notebook. This is another three-ring binder containing your data records and other notes you took as you investigated your topic. Display this along with your science report.

Display Board. Check the fair guidelines before beginning work on your display board: some fairs require boards of a certain size. Make your board attractive, but not distracting. Organize the information more or less sequentially, so your audience can follow the train of your project easily. Include your project title, original question and hypothesis, abstract, summary, procedure, experiment, data, and conclusion. You can include background research in your summary, and graphs, illustrations, and photographs in your experiment section. Here is an example:



Display Items. If you want to display objects from your experiment on your table at the fair, carefully check the guidelines to see if what you have is acceptable. ISEF fairs don't allow the display of any live materials (e.g., plants).

Oral Presentation. Many fairs require you to give an oral presentation of your project to the judges (especially in the upper levels) during a judging interview. Do not memorize a speech, but practice explaining your project to other people so you feel comfortable with the material. Prepare your explanation to last from 2-5 minutes, but be able to touch on every aspect of your project in more detail—sometimes your interview could last up to 15 minutes. Also prepare yourself for questions from the judges. For example, they might ask you what you found that you didn't expect, what your next step would be if you decided to continue the project, or why you think your research is important.

Judging Criteria. As you organize your display and prepare for your oral presentations, consult the judging criteria for your particular fair. Emphasize how you meet each category of criteria in your display and your speech. According to the ISEF Student Handbook, judges generally base their evaluations on the following points:

- Creative ability
- Scientific thought and engineering goals
- Thoroughness
- Skill
- Clarity

When you talk to the Judges:

- Smile
- Be enthusiastic
- Speak clearly (don't rush)
- Know your material
- Be specific
- Dress nicely

Science Fair Project Ideas

Start brainstorming for your science fair project right now! The following pages contain sample questions, keywords, and project ideas organized by age level and category. If you need other ideas, check the Science Projects page on our website, where projects and project ideas are added frequently.

Elementary School. Science fairs aren't just for older kids! Elementary students can learn a lot and have a great time doing their own projects. Some science fairs allow students in grades K-3 to do demonstration projects, but not all do. Check with your local science fair for K-3 rules regarding demonstration projects. If in doubt, it is always acceptable to do a real experiment. For 4-5th graders, a complete experiment that answers a question about science is usually required.

Life Science Ideas

- Have you noticed how the seeds in different kinds of fruit (like an apple and an orange) look very different from each other? Try growing seeds from different fruit that you've eaten, soaking them in water for one night and then planting them in a cup of dirt. Which kinds of seeds do you expect to grow best? (Which seed turns into the tallest plant after a month?) After doing the experiment, which seeds really grow best? Why do you think that might be?

- Lots of factors affect plant growth. Try experimenting with soil type, light, temperature, water, and more.

- A person's five senses are sight, smell, sound, taste, and touch. Compare sensitivity to touch in different parts of the body. Can you distinguish between an apple and a peach using your toes, knees, elbows, or belly? What about the difference between a sweater, sweatshirt, and t-shirt?

- Have you ever watched ants carrying bits of food? What food from your kitchen do you think an ant or other insect would like best? What "bait" will probably attract the greatest number of different insect species?

- Do a project to find out if temperature affects the butterfly life cycle. Make sure there is a 2-3 degree temperature difference between the caterpillars placed in a warm area versus those placed in a cooler area. For smaller creatures, you could hatch some brine shrimp. Is tap water or distilled water better for hatching the eggs?

- If you like collecting insects, perhaps you could design an experiment dealing with collecting techniques. What is the best method for softening butterfly wings so they can be mounted?

Earth Science Ideas

- The sun causes water to evaporate into the air, where it forms clouds and comes back down as rain or snow. Can wind speed, humidity, or temperature have an effect on the rate of evaporation?

- How good is soil at breaking things down? What can you find that is biodegradable? How can you test to see whether something is or not?

- What holds more water, sand or soil? How does this affect what kinds of plants can grow in each?

- Can you learn to predict the weather from the clouds? Try using a cloud chart to make your own forecast every day for a few weeks. How accurate was the cloud-forecast method?

Physical Science Ideas

- Can you use a magnet to find traces of iron in food, dollar bills, and other household materials? Are some magnets stronger than others? (Different magnets are available here.)

- What type of flooring creates the most or the least friction? Try carpet, wood, tile, linoleum, etc. Younger kids might test this by rolling a ball or toy truck over different surfaces.

- Why does a balloon stick to the wall after you rub it against your hair? Experiment with static electricity to find out how positive and negative charges in household items interact. What causes static electricity to increase? What are some ways to decrease static electricity and which methods work best?

- The sun gives off energy that can be used like a battery to power things. Connect a motor to a solar cell and figure out what conditions it runs best under. Do different types of light (such as fluorescent, incandescent, halogen, or LED light) power a solar cell better than others? What happens on a cloudy day? Older kids can research to find out what else solar energy can be used for.

- What makes a rainbow after a storm? Use a spectroscope to compare the spectra of different types of light. Do different light sources contain different colors of light?

- Experiment with the density of different liquids. Which is denser, oil, corn syrup, or water? If you add all three to the same glass, which liquid will float on top of the others? Compare how well some objects (e.g., raisin, paper clip) float in each of the three substances. You can also experiment with colored water (e.g., red for hot, blue for cold) to find out whether different temperatures affect water density.

Chemistry Ideas

- Design a science fair project comparing and contrasting how long it takes ice to melt at room temperature compared to a warm stovetop or the refrigerator.

- Your kitchen offers lots of chemistry ideas. How does cola or another soft drink compare in acidity with other common drinks or food? You can test acidity using pH paper. You can also test which fruits have the most vitamin C using indophenol.

- Water is sometimes called “the Universal Solvent” because it dissolves other substances so well. How well does water dissolve salt or sugar compared to other liquids (oil, corn syrup, or vinegar)?

- Make crystals from sugar, salt, and baking soda. How do their crystal shapes compare? Does the rate of evaporation of the crystal growing medium (water, vinegar) affect the size of the crystals? Does the rate of how fast the crystals cool down affect the size of the crystals? Do impurities (such as iodized salt versus salt that is not iodized) affect the growth of the crystals?

- Chemical energy can produce power! Try making a battery from food items. Which type of citrus fruit works best? What about vinegar?

- Experiment with polymers by using milk proteins to make homemade glue. How does homemade glue compare with commercial glue?

Middle School. The middle school years are important years to get excited about science. Now is a great time to start doing in-depth thinking on your own as you develop your problem-solving skills. Many of the ideas listed in the elementary school section can be converted into more complex middle school projects. All projects should use experimentation to answer a testable question.

Life Science Ideas

- Compare the germination of monocot seeds and dicot seeds. Experiment with different factors that affect germination speeds.
- Experiment with how the pH of soil affects plant growth. Develop an experiment that tests the importance of CO_2 to plant health.
- Do plants grow differently under different wavelengths of light (e.g., ultraviolet or fluorescent)?
- Design an experiment to discover the effects of abnormal radiation on plant growth, using irradiated seeds that are treated at different radiation levels.
- Use a microscope to study protozoa (find them in a local pond, or hatch them yourself). How do heat, light, water pH, and the use of quieting substances like methyl cellulose affect them? You could also do a pond water study to determine the various effects of pollutants on pond life.
- Experiment with the use of antibiotics and common household cleaners to fight bacteria growth.

Earth Science Ideas

- Experiment with the effects of erosion (by wind, water, ice, or gravity) on different soil types. Does vegetation in the soil slow erosion?
- Perform an acid test to discover if local minerals contain carbonate compounds.
- Find out how temperature, wind, or humidity affects the rate of evaporation.
- Sink holes are formed when the rock below the soil is dissolved by ground water. What kind of rock would present the most risk of a sink hole?

Physical Science Ideas

- Use a spectroscope to analyze the light spectra produced by burning different elements. Do you expect compounds that contain some of the same elements to have similar spectra?
- Build your own light bulb, and then experiment with what materials make the longest-lasting or brightest filament.
- Experiment with the most effective materials and design for propellers or model airplanes.
- What kind of substance (metal, ceramic) conducts heat the best? Do a thermal conductivity study to discover which substance works best for a pot handle and which works best for a teapot.
- Find out how increased mass affects velocity and acceleration by doing a project with dynamic carts. You can also experiment with the resulting velocities after a collision between a moving object and unmoving one, or between two objects moving in opposite directions.

- Experiment with the best way to build a solar oven to cook your own food.

Chemistry Ideas

- Try distilling drinkable water from salt water using the sun. What materials can you use to speed up the rate of evaporation?

- Make your own ink using different substances and compare how each withstands the effects of heat, light, or moisture. For example, does one type fade faster than another when they are heated or when exposed to strong light? If so, why?

- Use pennies to copper-plate an iron nail. See if pennies minted before 1982 (when they were 95% copper) make a thicker coating than newer pennies do (they only have 2.5% copper). How does the number of pennies you use affect the time it takes to plate the nail?

- Use a semi-permeable membrane to experiment with osmosis. What kinds of substances pass through the membrane, and what substances don't? What is a common property that prevents substances from passing through the membrane?

- Which retains heat longer, salt water or fresh water? Design an experiment to find out.

High School. Whether your goal is to compete in your school fair, or to win scholarships at the Intel ISEF, your experience in a high school science fair will stretch your knowledge, your creativity, and your ability. All high school projects should consist of a high level of original thought and development. To participate in upper-level competition, your project should be relevant to current science and technology, and should present a benefit to society. Start your brainstorming by taking a look at the ISEF categories; it's a good idea to check the ISEF guidelines, also, before you choose a topic. The following general topic ideas can help you define an area of interest that you can turn into your own unique question. (Remember, sometimes you will be working with dangerous materials—take every safety precaution!)

Life Science Ideas

- Compare the effect of antibiotics on gram-positive and gram-negative bacteria
- Test the effect of ultraviolet radiation on bacteria growth
- Investigate the sensitivity or resistance of common bacteria to antibacterial soap
- Experiment with plant genetics (plant hybrids, cross-breeding)
- Test factors that affect transpiration rates for plants
- Investigate effects of increased oxygen or carbon dioxide concentration on plant germination
- Find out the differences in properties and effects of organic vs. chemical fertilizers
- Test for harmful effects of pesticides; test or develop natural/organic alternatives; test the effectiveness of common pesticides such as DEET

Earth Science Ideas

- Explore methods of erosion prevention, test effects of soil composition on erosion
- Test the relationship between soil composition and water drainage
- Experiment with methods of flood management and containment
- Investigate the effects of sunspots on weather patterns
- Work with methods for forecasting weather
- Test the concentration and effect of minerals in soil and water samples

- Determine chemical makeup of rain in your area; test possible hazardous effects

Physical Science Ideas

- Test the effect of temperature and solute concentration on the refraction index of liquids
- Study acoustic models and methods of noise control
- Experiment with the effect of storage temperatures on batteries
- Develop improvements in battery chargers; try methods of using solar cells to recharge batteries
- Compare the bending strength of different building materials
- Test the effects of stress and strain on bridges
- Experiment with building materials that are fire-preventative
- Design industrial uses of magnets; test the effects of magnetic and electromagnetic fields on living organisms
- Develop design improvements for prosthetic devices

Chemistry Ideas

- Experiment with types, effectiveness, and the impact on nutritional value of preservatives in food.
- Compare the properties and effects of artificial sweetener vs. sugar or other natural sweeteners
- Test the effects of the pH level of a solution on the corrosion of iron and copper
- Explore different methods of corrosion prevention
- Experiment with different methods of water filtration/purification
- Test the chemical properties and physiological impact of saturated, unsaturated, and trans fats
- Investigate the role of enzymes and yeast in the fermentation process
- Test the effect of different cooking methods on the depletion of vitamin C in food
- Analyze the by-products of gasoline; compare efficiency of various octane levels

Environmental Science Ideas

- Test methods for cleaning up and neutralizing the effect of oil in salt water
- Work with methods of processing/recycling non-biodegradable items; experiment with decomposition aids
- Experiment with design and function of water or wind turbines
- Compare or develop methods of hydrogen production and storage for use in fuel cells
- Investigate methods of home insulation
- Experiment with expanded uses of solar energy.

Online Resources

For additional project ideas, try sciencebuddies.org. They have a good selection of detailed projects for junior high and high school.

You might also find our Tips for Internet Research article helpful.