Science Research and the Process of Science

Research is the process by which people create new knowledge about themselves or the world in which they live in order to answer a question or solve a problem. When choosing your topic, give careful thought to how your research might enhance the world and its inhabitants.

Questioning is probably the most important part of scientific creativity and is often followed by an "if...then" statement. Questioning usually leads to experiments or observations.

Good scientists, both young and old, use a process to study what they see in the world. The following six stages listed below will help you produce a good scientific experiment:

1) Be curious, choose a limited subject, ask a question; identify or originate/define a problem.*
2) Review published materials related to your problem or question.
3) Evaluate possible solutions and guess why you think it will happen (hypothesis).
4) Challenge and test your hypothesis through experimentation (data collection) and analysis.
5) Evaluate the results of your experiment and reach conclusions based on your data.
6) Prepare your report and exhibit.

Students should learn to be skeptical of all research results, especially their own. A good experiment may or may not answer the questions asked, but almost always leads to fresh questions requiring new experiments or observations. The experimental hypothesis is often developed after one has run a number of preliminary experiments, analyzed a body of results, and reached a tentative conclusion for your experiment.

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* All projects need sponsor approval; some projects need SRC/IRB approval prior to experimentation. Please reference the International Rules. If not attached, **the International Rules and other rules and forms guidance are available via our website at http://www.sciserv.org/isef/rules/**

All projects require at a minimum the completion of the **Checklist for Adult Sponsor, Research Plan (1A), Research Plan Attachment, Approval Form (1B)** and an **abstract**.

Goals of Engineering

Scientists try to understand how nature works; engineers create things that never were. An engineering project should state the engineering goals, the development process and the evaluation of improvements. Engineering projects may include the following steps:

1) Define a need.
2) Develop design criteria.
3) Search literature to see what has already been done.
4) Prepare preliminary designs.
5) Build and test a prototype.
6) Retest and redesign as necessary.

Intel International Science and Engineering Fair
Category Descriptions

Behavioral and Social Sciences
Human and animal behavior, social and community relationships—psychology, sociology, anthropology, archaeology, ethology, ethnology, linguistics, learning, perception, urban problems, reading problems, public opinion surveys, educational testing, etc.

Biochemistry
Chemistry of life processes—molecular biology, molecular genetics, enzymes, photosynthesis, blood chemistry, protein chemistry, food chemistry, hormones, etc.

Botany
Study of plant life—agriculture, agronomy, horticulture, forestry, plant taxonomy, plant physiology, plant pathology, plant genetics, hydroponics, algae, etc.

Chemistry
Study of nature and composition of matter and laws governing it—physical chemistry, organic chemistry (other than biochemistry), inorganic chemistry, materials, plastics, fuels, pesticides, metallurgy, soil chemistry, etc.

Computer Science
Study and development of computer hardware, software engineering, internet networking and communications, graphics (including human interface), simulations / virtual reality or computational science(including data structures, encryption, coding and information theory).

Earth Science
Geology, minerology, physiography, oceanography, meteorology, climatology, speleology, seismology, geography, etc.

Engineering
Technology; projects that directly apply scientific principles to manufacturing and practical uses—civil, mechanical, aeronautical, chemical, electrical, photographic, sound, automotive, marine, heating and refrigerating, transportation, environmental engineering, etc.

Environmental Science
Study of pollution (air, water, and land) sources and their control; ecology.

Mathematics
Development of formal logical systems or various numerical and algebraic computations, and the application of these principles—calculus, geometry, abstract algebra, number theory, statistics, complex analysis, probability.

Medicine and Health
Study of diseases and health of humans and animals—dentistry, pharmacology, pathology, ophthalmology, nutrition, sanitation, dermatology, allergies, speech and hearing, etc.

Microbiology
Biology of microorganisms—bacteriology, virology, protozoology, fungi, bacterial genetics, yeast, etc.

Physics
Theories, principles, and laws governing energy and the effect of energy on matter—solid state, optics, acoustics, particle, nuclear, atomic, plasma, superconductivity, fluid and gas dynamics, thermodynamics, semiconductors, magnetism, quantum mechanics, biophysics, etc.

Space Science
Astronomy, planetary sciences, etc.

Zoology
Study of animals—animal genetics, ornithology, ichthyology, herpetology, entomology, animal ecology, paleontology, cellular physiology, circadian rhythms, animal husbandry, cytology, histology, animal physiology, invertebrate neurophysiology, studies of invertebrates, etc.

Team Projects
Study conducted by two or three students in any discipline.

Getting Started

1) Pick Your Topic. Get an idea of what you want to study. Ideas might come from hobbies or problems you see that need solutions. Due to limited time and resources, you may want to study only one or two specific events.

2) Research Your Topic. Go to the library or internet and learn everything you can on your topic. Observe related events. Gather existing information on your topic. Look for unexplained or unexpected results. Also, talk to professionals in the field, write or email companies for specific information, and obtain or construct needed equipment.

3) Organize. Organize everything you have learned about your topic. At this point you should narrow your thinking by focusing on a particular idea. Your background research should help you.

4) Make a Timetable. Choose a topic that not only interests you, but can be done in the amount of time you have. Use a calendar to identify important dates. Leave time to fill out the forms and to review the Research Plan with your Sponsor. Certain projects require more time because they need prior Scientific Review Committee (SRC) or Institutional Review Board (IRB) approval. Allow plenty of time to experiment and collect data - even simple experiments do not always go as you might expect the first time or even the second time. Also leave time to write a paper and put together an exhibit.

5) Plan Your Experiments. Give careful thought to experimental design. Once you have a feasible project idea, write a research plan. This plan should explain how you will do your experiments and exactly what it will involve. All students participating in the Intel ISEF and affiliated fairs are required to complete the **Checklist for Adult Sponsor, Research Plan (1A)** and **Approval Form (1B)**.

6) Consult Your Adult Sponsor and Get Approvals. You are required to discuss your research plan with an Adult Sponsor and obtain a signature of approval. In reviewing **Research Plan (1A) with Research Attachment**, your Sponsor and you should determine if additional forms and/or IRB/SRC prior approvals are needed.

7) Conduct Your Experiments. During experimentation, keep detailed notes of each and every experiment, measurement, and observation. Do not rely on your memory. Remember to change only one variable at a time when experimenting, and make sure to include control experiments in which none of the variables are changed. Make sure you include sufficient numbers in both control and experimental groups to be statistically valid.

8) Examine Your Results. When you complete your experiments, examine and organize your findings. Did your experiments give you the expected results? Why or why not? Was your experiment performed with the exact same steps each time? Are there other explanations that you had not considered or observed? Were there errors in your observations? Remember that understanding errors and reporting that a suspected variable did not change the results can be valuable information. If possible, statistically analyze your data.

9) Draw Conclusions. Which variables are important? Did you collect enough data? Do you need to conduct more experimentation? Keep an open mind - never alter results to fit a theory. If your results do not support your hypothesis, you still have accomplished successful scientific research.

Elements of a Successful Project

1) PROJECT DATA BOOK

A project data book is your most treasured piece of work. Accurate and detailed notes make a logical and winning project. Good notes show consistency and thoroughness to the judges, and will help you when writing your research paper.

2) ABSTRACT

After finishing research and experimentation, you need to write a (maximum) 250-word, one-page abstract. An abstract should include the (a) purpose of the experiment, (b) procedures used, (c) data, and (d) conclusions. It also may include any possible research applications. Only minimal reference to previous work may be included. The abstract must focus on work done since the last fair and should not include: a) acknowledgments, or b) work or procedures done by the mentor. See below for an example of an appropriately written abstract. See page 24 of the International Rules for the proper formatting of an Official Intel ISEF Abstract and Certification.

Sample Abstract

Effects of Marine Engine Exhaust Water on Algae
Jones, Mary E.
Hometown High School, Hometown, PA

This project in its present form is the result of bioassay experimentation on the effects of two-cycle marine engine exhaust water on certain green algae. The initial idea was to determine the toxicity of outboard engine lubricant. Some success with lubricants eventually led to the formulation of "synthetic" exhaust water which, in turn, led to the use of actual two-cycle engine exhaust water as the test substance.

Toxicity was determined by means of the standard bottle or "batch" bioassay technique. *Scenedesmus quadricauda* and *Ankistrodesmus* sp. were used as the test organisms. Toxicity was measured in terms of a decrease in the maximum standing crop. The effective concentration - 50% (EC50) for *Scenedesmus quadricauda* was found to be 3.75% exhaust water; for *Ankistrodesmus* sp. 3.1% exhaust water using the bottle technique.

Anomalies in growth curves raised the suspicion that evaporation was affecting the results; therefore, a flow-through system was improvised utilizing the characteristics of a device called a Biomonitor. Use of a Biomonitor lessened the influence of evaporation, and the EC 50 was found to be 1.4% exhaust water using Ankistrodesmus sp. as the test organism. Mixed populations of various algae gave an EC 50 of 1.28% exhaust water.

The contributions of this project are twofold. First, the toxicity of two-cycle marine engine exhaust was found to be considerably greater than reported in the literature (1.4% vs. 4.2%). Secondly, the benefits of a flow-through bioassay technique utilizing the Biomonitor was demonstrated.

3) RESEARCH PAPER

A research paper should be prepared and available along with the project data book and any necessary forms or relevant written materials. A research paper helps organize data as well as thoughts. A good paper includes the following sections:

a) Title Page and Table of Contents. The title page and table of contents allows a reader to follow the organization of the paper quickly.

b) Introduction. The introduction sets the scene for your report. The introduction includes your hypothesis, problem or engineering goals, an explanation of what prompted your research, and what you hoped to achieve.

c) **Materials & Methods.** Describe in detail the methodology you used to collect data, make observations, design apparatus, etc. Your report should be detailed enough so that someone would be able to repeat the experiment from the information in your paper. Include detailed photographs or drawings of self-designed equipment. Only include this year's work.

d) **Discussion.** The discussion is the essence of your paper. The results and conclusions should flow smoothly and logically from your data. Be thorough. Allow your readers to see your train of thought, letting them know exactly what you did. Compare your results with theoretical values, published data, commonly held beliefs, and/or expected results. Include a discussion of possible errors. How did the data vary between repeated observations of similar events? How were your results affected by uncontrolled events? What would you do differently if you repeated this project? What other experiments should be conducted?

e) **Conclusion.** Briefly summarize your results. Be specific, do not generalize. Never introduce anything in the conclusion that has not already been discussed.

f) **Acknowledgments.** You should always credit those who assisted you, including individuals, businesses, and educational or research institutions.

g) **References/Bibliography.** Your reference list should include any documentation that is not your own *(i.e.*, books, journal articles). See an appropriate reference in your discipline for format. For instance, APA style:

(1) Journal article, one author -
Bekerian, D.D. (1993). In search of the typical eyewitness. American Psychologist, 48. 574-576.

(2) Reference to an entire book -
Cone, J.D., & Foster, S.L. (1993. Dissertations and theses from start to finish: Psychology and related fields. Washington, DC: American Psychological Association.

4) VISUAL DISPLAY

You want to attract and inform. Make it easy for interested spectators and judges to assess your study and the results you have obtained. Make the most of your space using clear and concise displays. Please be sure to reference the Display and Safety Rules on pages 9-11 of the International Rules; this information is also available on the Science Service website at www.sciserv.org.

Helpful Hints for Display:

a) **Current Year.** Make sure the display reflects the current year's work only.

b) **A Good Title**. Your title is an extremely important attention-grabber. A good title should simply and accurately present your research. The title should make the casual observer want to know more.

c) **Take Photographs.** Many projects involve elements that may not be safely exhibited at the fair, but are an important part of the project. You might want to take photographs of important parts/phases of your experiment to use in your display. Photographs or other visual images of human test subjects must have informed consent (Human Subjects Form 4) (please see page 5 of the International Rules.

d) **Be Organized.** Make sure your display is logically presented and easy to read. A glance should permit anyone (particularly the judges) to locate quickly the title, experiments, results, and conclusions. When you arrange your display, imagine that you are seeing it for the first time.

e) **Eye-Catching.** Make your display stand out. Use neat, colorful headings, charts, and graphs to present your project. Pay special attention to the labeling of graphs, charts, diagrams, and tables to ensure that each has a title and appropriate label describing what is being demonstrated. Anyone should be able to understand the visuals without further explanation.

f) **Correctly Presented and Well-Constructed.** Be sure to adhere to the size limitations and safety rules when preparing your display. Display all required forms for your project. Make sure your display is sturdy, as it will need to remain intact for quite a while. Do not hesitate to ask for advice from adults if you need it.

Judging

Judges evaluate and focus on 1) what the student did in the current year; 2) how well a student followed the scientific methodologies; 3) the detail and accuracy of research as documented in the data book; and 4) whether experimental procedures were used in the best possible way.

Judges look for well thought-out research. They look at how significant your project is in its field, how thorough you were, and how much of the experiment thought and design is your own work.

Judges applaud those students who can speak freely and confidently about their work. They are not interested in memorized speeches - they simply want to TALK with you about your research to see if you have a good grasp of your project from start to finish. Judges often ask questions to test your insight into your projects such as "What was your role?", "What didn't you do?" and "What would be your next step?"

INTEL ISEF JUDGING CRITERIA (points)

	Individual	Team
Creative Ability	30	25
Scientific Thought and Engineering Goals	30	25
Thoroughness	15	12
Skill	15	12
Clarity	10	10
Teamwork	---	16

Patent and Copyright Information

You may want to consider applying for a patent or copyright if you want to protect your work. You can contact the Office of Public Affairs, U.S. Patent Office, at 703/305-8341 for Patent information or the Library of Congress at 202/707-3000 for copyright information.