2011 Student Handbook

Science Research and the Process of Science

Research is a process by which people discover or create new knowledge about the world in which they live. The Intel ISEF and Affiliated Fairs are research (data) driven. Students design research projects that provide quantitative data through experimentation followed by analysis and application of that data. Projects that are demonstrations, 'library' research or informational projects, 'explanation' models or kit building are not appropriate for research based science fairs.

Questioning is probably the most important part of a scientific investigation and is often followed by an "if...then" statement. Students are encouraged to design 'controlled' experiments, ones that allow them to set up a standard and then change only one variable at a time to see how that variable might affect the original condition tested as the standard. Thus, questioning usually leads to experiments or observations.

Good scientists, both young and old, frequently use a process to study what they see in the world. This process has been referred as the 'Scientific Method' or more recently as the 'Inquiry Cycle'. The following 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. It is important that this question be a 'testable' question – one in which data is taken and used to find the answer. A testable question can further be identified as one in which one or more variables can be identified and tested to see the impact of that variable on the original set of conditions. The question should not merely be an 'information' question where the answer is obtainable through literature research.
2) Review published materials related to your problem or question. This review should also include reviewing the International Rules and Guidelines (www.societyforscience.org/isef/rulesandguidelines). This is called background research.
3) Evaluate possible solutions and guess why you think it will happen (hypothesis).
4) Experimental design (procedure). In designing the experiment, it is critical that only one variable – a condition that may effect the results of the experiment – is changed at a time. This makes the experiment a 'controlled' experiment.
5) Challenge and test your hypothesis through your procedure of experimentation (data collection) and analysis of your data. Use graphs to help see patterns in the data.
6) Draw conclusions based on empirical evidence from the experiment.
7) Prepare your report and exhibit.
8) Review and discuss the findings with peer group/professional scientists
9) New question(s) may arise from your discussions.

This sets the stage for another research project as new questions are raised from others and the process repeats itself. The hypothesis often changes during the course of the experiment. Supporting or not supporting your hypothesis is secondary to what is learned and discovered during the research.

Non Inquiry Based Research

Not all areas of study are best served by scientific method based research. Because engineers, inventors, mathematicians, theoretical physicists, and computer programmers have different objectives than those of other scientists, they follow a different process in their work. The process that they use to answer a question or solve a problem is different depending on their area of study. Each one uses their own criteria to arrive at a solution.

Engineering Projects

"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:

1) Define a need or "How can I make this better?"
2) Develop or establish design criteria (could be more than one)
3) Do background research and search the literature to see what has already been done or what products already exist that fill a similar need. What makes them good and what makes them weak?
4) Prepare preliminary designs and a materials list. Consider costs, manufacturing and user requirements.
5) Build and test a prototype of your best design. Consider reliability, repair and servicing.
6) Retest and redesign as necessary. Product testing.
7) Present results.

Computer Science Projects

These often involve creating and writing new algorithms to solve a problem or improve on an existing algorithm. Simulations, models or 'virtual reality' are other areas on which to conduct research.

Mathematics Projects

These involve proofs, solving equations, etc. Math is the language of science and is used to explain existing phenomena or prove new concepts and ideas.

Theoretical Projects

These projects may involve a thought experiment, development of new theories and explanations, concept formation or designing a mathematical model.

Getting Started

1) **Pick your topic:** This is perhaps the most difficult part. Get an idea of what you want to study or learn about. Ideas should come from things in your areas of interest. A hobby might lead you to a good topic. What is going on in the world that you would like to know more about? Most importantly, pick a question or problem that is not too broad and that can be answered through scientific investigation.

2) **Research Your Topic:** Go to the library or internet to learn more about your topic. Always ask Why or What if.... Look for unexplained or unexpected results. Also, talk to professionals in the field.

3) **Organize:** Organize everything you have learned about your topic. At this point, you should narrow your thinking by focusing on a particular idea.

4) **Make a Time Table:** Choose a topic that not only interests you, but can be done in the amount of time you have. Identify your 'testable question'. Develop a time line to manage your time efficiently. You will need time to fill out the necessary forms and to review the research plan with your sponsor. Certain projects will require more time because they need prior approval from the Scientific Review Committee (SRC) or Institutional Review Board (IRB). Allow plenty of time to experiment and collect data. You will also need time to write a paper and put together a display or 'board'.

5) **Plan Your Experiment:** 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 will be involved. Remember you must design your experiment so that it is a 'controlled' experiment. This is one in which only one variable is changed at a time. The results are then compared to the 'standard' data you take originally before you change that one variable. Thus, you have designed an investigation with adequate control and limited variables to investigate a question. Also, in your experimental design, make sure you include sufficient numbers in both control (if applicable) and experimental groups to be statistically valid. The experimental design should also include a list of materials. Once finished with the experimental design (called 'procedure') all students are required to fill out the appropriate forms.

6) **Consult with 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 your research plan, you should determine if additional forms and prior approval are needed.

7) **Conduct Your Experiment:** During experimentation, keep detailed notes of each and every experiment, measurement and observation in a log book. Do not rely on memory. Besides, judges love logbooks! Use data tables or charts to record your quantitative data.

8) **Analyze Your Results:** When you complete your experiments, examine and organize your findings. Use appropriate graphs to make 'pictures' of your data. Identify patterns from the graphs. This will help you answer your testable question. Did your experiments give you the expected results? Why or why not? Was your experiment preformed with the exact same steps each time? Are there other explanations that you had not considered or observed? Were there experimental errors in your data taking, experimental design or observations? Remember, that understanding errors is a key skill scientists must develop. In addition, reporting that a suspected variable did not change the results can be valuable information. That is just as much a 'discovery' as if there was some change due to the variable. In addition, statistically analyze your data using the statistics that you can understand and explain their meaning.

9) **Draw Conclusions:** Did the variable(s) tested cause a change when compared to the standard you are using? What patterns do you see from your graph analysis that exist between your variables? 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, that's ok and in some cases good! Try to explain why you obtained different results than your literature research predicted for you. Were there sources of error that may have caused these differences? If so, identify them. Even if the results do differ, you still have accomplished successful scientific research because you have taken a question and attempted to discover the answer through quantitative testing. This is the way knowledge is obtained in the world of science. Think of practical applications that can be made from this research. How could this project be used in the real world? Finally, explain how you would improve the experiment and what would you do differently.

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. Data tables are also helpful. They may be a little 'messy' but be sure the quantitative data recorded is accurate and that units are included in the data tables. Make sure you date each entry.

2) 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 the reader to follow the organization of the paper quickly.

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

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

d) **Results:** The results include data and analysis. This should include statistics, graphs, pages with your raw collected data, etc.

e) **Discussion:** This is the essence of your paper. 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?

f) **Conclusions:** Briefly summarize your results. State your findings in relationships of one variable with the other. Support those statements with empirical data (one average compared to the other average, for example). Be specific, do not generalize. Never introduce anything in the conclusion that has not already been discussed. Also mention practical applications.

g) You should always credit those who have assisted you, including individuals, businesses and educational or research institutions. However, acknowledgments listed on a project board are a violation of D & S Display rules and must be removed.

h) **References/Bibliography:** Your reference list should include any documentation that is not your own (i.e. books, journal articles, websites, etc.). See an appropriate reference in your discipline for format or refer to the Instructions to Authors of the appropriate publication.

Three common reference styles are:

APA (American Psychological Association) **Style** :

http://apastyle.apa.org/
http://www.calvin.edu/library/knightcite/index.php
http://owl.english.purdue.edu/owl/resource/560/01/
This resource offers examples for the general format of APA research papers, in-text citations, endnotes/footnotes, and the reference page.

MLA (Modern Language Association) **Format:**

http://www.mla.org/style
http://www.calvin.edu/library/knightcite/index.php
http://owl.english.purdue.edu/owl/resource/557/01/
This resource offers examples for the general format of MLA research papers, in-text citations, endnotes/footnotes, and the Works Cited page.

Chicago Manual of Style

http://www.chicagomanualofstyle.org/home.html
http://www.calvin.edu/library/knightcite/index.php

The Chicago Manual of Style presents two basic documentation systems. The more concise author-date system has long been used by those in the physical, natural, and social sciences. In this system, sources are briefly cited in the text, usually in parentheses, by author's last name and date of publication. The short citations are amplified in a list of references, where full bibliographic information is provided.

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 1-800-786-9199 for Patent information or the Library of Congress at 202-707-3000 for copyright information.

3) **Abstract:**

After finishing research and experimentation, you need to write an abstract. The abstract needs to be a maximum of 250 words on one page. An abstract should include the a) purpose of the experiment, b) procedures used, c) data, and 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 in the current year 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 23 of the International Rules for the proper formatting of an Official Intel ISEF Abstract and Certification. <u>Please Note:</u> The Official abstract form is only for those participating in ISEF and may not be required for many Affiliated or local fairs.

Sample Abstract

Effects of Marine Engine Exhaust Water on Algae
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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.

International Rules & Guidelines

www.societyforscience.org/isef/rulesandguidelines

The rules were developed to facilitate the following:

- protect the rights and welfare of the student researcher and human subjects
- protect the health and well-being of vertebrate animal subjects
- follow federal regulations governing research
- offer guidance to affiliated fairs
- use of safe laboratory practices
- address environmental concerns

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. You want to 'catch the eye' of the judges and convince them that the research is of sufficient quality to deserve closer scrutiny. Most displays or boards have three sections and are free standing. For the most part, the displays are put on a table. Most Intel ISEF judges get a chance to look at the board before the interviews. Make the most of your space using clear and concise displays. You never get a second chance to make a first impression! Please be sure to reference the Display and Safety Rules in the International Rules and Guidelines; this information is also available on the Society for Science & the Public website at www.societyforscience.org.

Helpful hints for display:

a) **Current Year:** Make sure the board reflects the current year's work only. Prior year's data books are permitted at your project.

b) **Good Title:** Your title is an extremely important attention-grabber. A good title should simply and accurately present your research and depict the nature of the project. 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. Photograph or other visual images of human test subjects must have signed consent forms. Credit must be given for all photographs.

d) **Be Organized:** Make sure your display follows a sequence and is logically presented and easy to read. Reach out to the 'skim-reader'. A glance should permit anyone (particularly the judges) to locate quickly the title, abstract, experiments, results and conclusions. When you arrange your display, imagine that you are seeing it for the first time. Highlight your results using key graphs that show the relationships of the two variables tested. Use the graphs to give a 'picture' of the data for your viewers. These graphs will provide an easier method of viewing the data rather than just seeing the recorded quantitative data.

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 or graphs, charts, diagrams, photographs, 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. You must also consider the weight of the project for shipping. It can be very costly to ship a heavy board. Keep your materials light, but strong.

Please Note: The judges are judging your research, not the display. So don't spend an excessive amount of time or money on the board. You are being judged on the science not the show!

5) **Judging**

Judges evaluate and focus on 1) what the student did in the current year; 2) how well a student followed the scientific, engineering, computer programming or mathematical 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 it's field; how thorough you were, and how much of the experiment thought and design is your own work.

Initially, judges get their information from your board, abstract and research paper to learn what the project is about, but it is the **Interview** that will be the final determination of your work. Judges applaud those students who can speak freely and confidently about their work. They are not interested in memorized speeches or presentations – 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. It is important to start the interview off right. Greet the judges and introduce yourself. You want to make a good first impression. Appearance, good manners, appropriate attire, and enthusiasm for what you are doing will impress the judges.

Judges often ask questions to test your insight into your projects such as: "How did you come up with this idea? "What was your role?", "What didn't you do?", "What further plans do you have to continue research?" and "What are the practical applications of your project?" Remember that the judges need to see if you understand the basic principles of science behind your project or topic area. They want to determine if you have correctly measured and analyzed the data. They want to know if you can determine possible sources of error in your project and how you might apply your findings to the 'real' world. Finally, the judges seek to encourage you in your scientific efforts and your future goals/career in science. Relax, smile and enjoy your time to learn from them and accept their accolades for your fine work.

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