

Forward

At the core of the secondary science program is the belief that students have the right and need to think scientifically and solve problems according to the scientific method. This Advanced Independent Research curriculum guide has been compiled to help students attain this goal in several ways.

First, a project of this scope is an excellent vehicle which allows students to apply many skills he or she has obtained during their formal educational training through the use of reading, library skills, grammar, communication skills, mathematics, logic, art, organizational skills, and science. The projects not only provide a means to encourage students to achieve academically, but also foster confidence and self esteem as well as provide numerous scholarship and monetary rewards.

Second, by enabling students to focus on scientific research, an ideal learning environment which is both wildly exciting and stimulating can be achieved.

Third, students will gain an appreciation for the process of conducting pure scientific research. Students will understand that much can be learned from performing an experiment even if it does not yield desired results. Students will recognize that often many more questions arise that must be explored. Science is about exploration and scientists may spend a lifetime in search of “the answer.” Even so, their results are valuable.

Time Line for Advanced Independent Research (six weeks)

First Six Weeks

- Complete procedure less lab to determine students' prior knowledge of the scientific method.
- With the aid of your librarian, learn proper research skills. Spend time at school, community, and college libraries. This is a valuable skill that students will carry with throughout their educational career.

Second Six Weeks

- Continue with research and complete the background search for the research.
- Students will need to receive their SRC booklets and become familiar with the rules governing the International Science and Engineering Fair.
- A statistical analysis unit may fit well here. This will give students knowledge so they will develop better methodologies.
- Test students over their knowledge of the Library and SRC.
- Several competitions have deadlines during this time. Encourage students to become involved in these competitions.
- Begin Experimental design.

Third Six Weeks

- Students will complete development of the methodology and begin collection of data.

Fourth Six Weeks

- Complete analysis of data
- Complete Backboard for District Fair

Fifth Six Weeks

- Refinement of an overall project for Regional, State and International Fairs.
- Development of audiovisual presentation for such competitions as TJAS.

Sixth Six Weeks

- Involvement in several area competitions
- Exposure to professionals in scientific fields.
- Analysis of a fictional novel for scientific basis

Core Objectives- Advanced Independent Research

To improve research skills directly related to the use of the library resources.

- Master the use of microfiche, SIRS, Newsbank, vertical files and Info Trac.
- Introduce students to a collegiate level library.

To develop competence on use of the Internet and engage this tool in the use of scientific research

- Correctly execute the following searches-Archie (FTP search), Browser searches, Veronica search, or use of INTERNET explorer or web crawler
- Correctly log onto the Internet/WWW.
- Successfully write and receive e-mail with leading authorities in appropriate research fields.
- Correctly search for items on the web which relate to science fair research.
- Include current web sites as a source for research paper. At least 10% of the sources for the research paper should come from this format.

To learn structure and organize research efficiently

- Master the skill of gathering information from many sources through the use of the index cards.
- Develop an outline for the background search.
- Develop organizational skills that will lead to quick retrieval of materials.

To become competent with the rules governing International Science and Engineering Fair (ISEF)

- Read and analyze the SRC booklet
- Complete appropriate forms associated with the research.

To improve scientific research skills and enhance oral presentation techniques

- Keep a detailed log of research.
- Master proper use of APA bibliography and writing techniques
- Compare and contrast the APA style and the MLA style of writing.
- Execute a scientific presentation using Power Point or similar software.
- Develop proper public speaking techniques with emphasis on proper gesture, posture, voice projection and inflections.
- Prepare an audiovisual presentation which may be presented in competition.

To master techniques which will lead to the development of a competitive science fair project

- Focus on open ended labs which in able students to review proper protocol for research
- State a variety of possible problems.
- Formulate a well-thought out hypothesis.
- Develop a methodology to test the hypothesis.
- Collect and analyze data (See Objective #8)
- Draw conclusions supported by the data collected.
- Develop applications for current research.

To learn new research and laboratory techniques

- Introduce the students to specialized procedures and equipment needed for microbial research.
- Introduce students to specialized equipment such as an autoclave, spectrophotometer, ultracentrifuge, etc.
- Students will demonstrate proficiency in the operation of research equipment before they assume use on their own.

To write a scientific research paper which includes the following components: introduction, materials and methods, results, discussion and conclusions, application. Future research, references, and acknowledgements

To gain a better understanding of statistics and statistical analysis and how they apply to the students' research

- To be familiar with the use of statistical representation of data to depict a realistic and accurate view of the results.
- To know and apply terms such as mean, median, mode, standard, deviation, population deviation, 1 st quartile, 3 rd quartile, outliers.
- To utilize terms mentioned above to enhance the presentation of statistical information.
- To analyze and construct bar graphs, line graphs, stem-and-leaf plots, and histograms and apply theme to the research conclusion.
- To gain experience in the manipulation of data through calculation tools such as TI – 82 and the Statistic computer program.

To Create a professional and effective backboard and presentation that clearly promotes the student research

- Learn to use graphics programs for charts, graphs, and labels.
- To speak fluently and effectively about the research project through practice interviews.

To promote interest in science fair and become further acquainted with the scientific world

- Display boards and posters throughout the school
- Encourage optional presentations for science classes
- Involve the school in research through surveys and experimentation.

To represent school in science related competitions in order to enhance individual scientific knowledge

- Participate in a variety of competitions or other UIL competition.
- Prepare a project for school, district, regional, state, and International science fair.
- Successfully execute research which will lead to presentations and competitions.
- Submit an application to Texas Junior Science, Engineering and Humanities Symposium
- Compete at Texas Junior Academy of Sciences and qualify for National Junior Academy of Sciences.
- Develop and invitational symposium for Team Science fair Projects.
- Develop an appreciation for lectures given by guest speakers covering various related topics.

To explore careers available in the scientific community

- Learn about different professions available in the scientific community through interactions with professionals in the field.
- Tour a scientific facility to gain first hand experience
- Explore the relevance of the student's project in reference to real world situations and applications.
- Read a fictitious science based novel and identify the factual information from fiction through library research.
- Participate in field trips to various sites such as The Science Place, Omni, The Outdoor Learning Center, etc.

To learn how to successfully publish a scientific research paper

- Locate proper journals that would apply to the students' research.
- Seek out and identify journals at a University library to find the publication company.
- Ensure that the students' research meets the requirements located in the journal
- Write a cover letter to the publishers briefly describing the research and its merit and give appropriate personal information.
- If the paper is rejected, repeat the process or alter paper to meet requirements.
- Publish paper on online sites which are specifically tailored to the student research such as the Empiricist (address)

EXPERIMENTAL (An Intermediate Level Guide)

SCIENCE

PROJECTS

INTRODUCTION

There Are Different Forms of the Scientific Method

A confusing aspect of science is that not all fields of science arrive at conclusions in the same way. The physical sciences, like physics and chemistry, use experimental forms of the "scientific method." The physical sciences do experiments to gather numerical data from which relationships are derived, and conclusions are made. The more descriptive sciences, like zoology and anthropology, may use a form of the method that involves gathering of information by visual observation or interviewing. What is common among all sciences, however, is the making of hypothesis to explain observations, the gathering of data, and based on this data, the drawing of conclusions that confirm or deny the original hypothesis. The difference is in what is considered data, and how data is gathered and processed.

Data for a physical scientist is numbers. The numbers are often plotted on graphs. Graphs can be used to derive equations that can be used for making predictions. Data, for an anthropologist, could be a recorded interview. Interviews can be compared to other related information. Hence the distinction between the exact sciences (physical sciences that use numbers to measure and calculate results), and other sciences that use descriptions and inferences to arrive at results. If you are not aware of this difference, you could produce a written report for your science project. Your project will then only show what you know about something instead of experimentally answering questions you have about observations you have made. The information given below assumes you are doing an experimental science project that uses the experimental method to gather data and test hypothesis.

What is the Experimental Scientific Method?

The steps listed below will help you systematically investigate observations that can be tested with the experimental method. Not all questions can be dealt with by the experimental scientific method. You must choose a question or problem that can be formulated in terms of hypothesis that can be tested. Tests done to check hypothesis are called experiments. To design a suitable experiment you must make an educated guess about the things that affect the system you want to investigate. These are called variables. This requires thought, information gathering, and a study of the available facts relating to your problem. As you do experiments, you will record data that measures the effect of variables. Using this data you can calculate results. Results are presented in the form of tables or graphs. These results will show you trends related to how the variables affect the system you are working with. Based on these trends, you can draw conclusions about the hypothesis you originally made.

What Makes the Scientific Method Possible?

The existence of "cause and effect relationships" in nature is what makes experimental science possible. Hypothesis can only be verified using the scientific method described here if there is a cause and effect relationship between the variables you have chosen and the system you are studying.

What Is Experimental Science?

Experimental science is actually the search for cause and effect relationships in nature. A hypothesis is your best guess at what this cause and effect relationship is. Your conclusions will allow you to predict the result of future cause and effect relationships. If you can do this, you can harness effects to do things. Technology is the area that applies the findings of the sciences to produce machines, or do things for us.

STEPS IN DOING AN EXPERIMENTAL SCIENCE PROJECT

The steps in the experimental scientific method as usually presented are: Observation, Hypothesis, Controlled Experiment, Conclusion. To actually do a science experiment, many more steps are needed. The following more accurately reflects the course of an actual experimental investigation.

Initial Observation

You notice something, and wonder why it happens. You see something and wonder what causes it. You want to know how or why something works. You ask questions about what you have observed. You want to investigate. The first step is to clearly write down exactly what you have observed.

Information Gathering

Find out about what you want to investigate. Read books, magazines or ask professionals who might know in order to learn about the effect or area of study. Keep track of where you got your information from.

Title the Project

Choose a title that describes the effect or thing you are investigating. The title should be short and summarize what the investigation will deal with.

State the Purpose of the Project

What do you want to find out? Write a statement that describes what you want to do. Use your observations and questions to write the statement.

Identify Variables

Based on your gathered information, make an educated guess about what types of things affect the system you are working with. Identifying variables is necessary before you can make a hypothesis.

Make Hypothesis

When you think you know what variables may be involved, think about ways to change one at a time. If you change more than one at a time, you will not know what variable is causing your observation. Sometimes variables are linked and work together to cause something. At first, try to choose variables that you think act independently of each other. At this point, you are ready to translate your questions into hypothesis. A hypothesis is a question which has been reworded into a form that can be tested by an experiment.

Make a list of your answers to the questions you have. This can be a list of statements describing how or why you think the observed things work. These questions must be framed in terms of the variables you have identified. There is usually one hypothesis for each question you have. You must do at least one experiment to test each hypothesis. This is a very important step. If possible, ask a scientist to go over your hypothesis with you.

Design Experiments to Test Your Hypothesis

Design an experiment to test each hypothesis. Make a step-by-step list of what you will do to answer each question. This list is called an experimental procedure. For an experiment to give answers you can trust, it must have a "control." A control is an additional experimental trial or run. It is a separate experiment, done exactly like the others. The only difference is that no experimental variables are changed. A control is a neutral "reference point" for comparison that allows you to see what changing a variable does by comparing it to not changing anything. Dependable controls are sometimes very hard to develop. They can be the hardest part of a project. Without a control you cannot be sure that changing the variable causes your observations. A series of experiments that includes a control is called a "controlled experiment."

Experiments are often done many times to guarantee that what you observe is reproducible, or to obtain an average result. Reproducibility is a crucial requirement. Without it you cannot trust your results. Reproducible experiments reduce the chance that you have made an experimental error, or observed a random effect during one particular experimental run.

Some Guidelines for Experimental Procedures

- Select only one thing to change in each experiment. Things that can be changed are called variables.
- Change something that will help you answer your questions.
- The procedure must tell how you will change this one thing.
- The procedure must explain how you will measure the amount of change.
- Each experiment should have a "control" for comparison so that you can see what the change actually did.

Obtain Materials and Equipment

Make a list of the things you need to do the experiment, and prepare them. If you need special equipment, a local college or business may be able to loan it to you. Another source of science materials are mail order supply houses such as Edmund Scientific in Barrington, New Jersey (phone 1-609-457-8880 for a catalog). Professional science supply houses are located in larger cities. They will have just about anything you will need.

Do the Experiments and Record Data

Experiments are often done in series. A series of experiments can be done by changing one variable a different amount each time. A series of experiments is made up of separate experimental "runs." During each run you make a measurement of how much the variable affected the system under study. For each run, a different amount of change in the variable is used. This produces a different amount of response in the system. You measure this response, or record data, in a table for this purpose. This is considered "raw data" since it has not been processed or interpreted yet. When raw data gets processed mathematically, for example, it becomes results.

As you do experiments, record all numerical measurements made. Data can be amounts of chemicals used, how long something is, the time something took, etc. If you are not making any measurements, you probably are not doing an experimental science project.

Record Your Observations

Observations can be written descriptions of what you noticed during an experiment, or problems encountered. Keep careful notes of everything you do, and everything that happens. Observations are valuable when drawing conclusions, and useful for locating experimental errors.

Perform Calculations

Do any calculations needed from your raw data to obtain the numbers you need to draw your conclusions. For example, you weighed a container. This weight is recorded in your raw data table as "wt. of container." You then added some soil to the container and weighed it again. This would be entered as "wt. of container + soil." In the calculation section, do the calculation to find out how much soil was used in this experimental run:

$$(\text{wt. of container} + \text{soil}) - (\text{wt. of container}) = \text{wt. of soil used}$$

Each calculated answer is entered into a table in a Results section.

Not all experiments need a calculation section. However, if you do not have any calculations you may not be using the experimental scientific method. If you have calculations to make, you probably are using the experimental scientific method.

Summarize Results

Summarize what happened. This can be in the form of a table of processed numerical data, or graphs. It could also be a written statement of what occurred during experiments.

It is from calculations using recorded data that tables and graphs are made. Studying tables and graphs, we can see trends that tell us how different variables cause our observations. Based on these trends, we can draw conclusions about the system under study. These conclusions help us confirm or deny our original hypothesis. Often, mathematical equations can be made from graphs. These equations allow us to predict how a change will affect the system without the need to do additional experiments. Advanced levels of experimental science rely heavily on graphical and mathematical analysis of data. At this level, science becomes even more interesting and powerful.

Draw Conclusions

Using the trends in your experimental data and your experimental observations, try to answer your original questions. Is your hypothesis correct? Now is the time to pull together what happened, and assess the experiments you did.

Other Things You Can Mention in the Conclusion

- If your hypothesis is not correct, what could be the answer to your question?
- Summarize any difficulties or problems you had doing the experiment.
- Do you need to change the procedure and repeat your experiment?
- What would you do different next time?
- List other things you learned.

Try to Answer Related Questions

What you have learned may allow you to answer other questions. Many questions are related. Several new questions may have occurred to you while doing experiments. You may now be able to understand or verify things that you discovered when gathering information for the project. Questions lead to more questions, which lead to additional hypothesis that need to be tested.

EXPERIMENTAL ERRORS

Can I Trust My Results?

If you did not observe anything different than what happened with your control, the variable you changed may not affect the system you are investigating. If you did not observe a consistent, reproducible trend in your series of experimental runs there may be experimental errors affecting your results. The first thing to check is how you are making your measurements. Is the measurement method questionable or unreliable? Maybe you are reading a scale incorrectly, or maybe the measuring instrument is working erratically.

If you determine that experimental errors are influencing your results, carefully rethink the design of your experiments. Review each step of the procedure to find sources of potential errors. If possible, have a scientist review the procedure with you. Sometimes the designer of an experiment can miss the obvious.

Random Errors

If your measurement method is not the cause, try to determine if the error is systematic or random. Random errors are more obvious. They result in non-reproducible data that doesn't make sense. In this case, runs with the same combination of variables, and even the control itself, cannot be duplicated. Some randomness is always present in nature. No two measurements are exactly the same. You must judge if the differences in your data can be explained by nature operating normally.

A random error may be occurring because you are doing something differently in each run. For example, you are not careful in cleaning your reaction vessels and some of the chemicals are being carried over from the last experiment. Scientists use various statistical tests to determine if the difference between runs is due to randomness in nature, or to the way they are doing the experiments.

Systematic Errors

Systematic errors are harder to find. Your data and results may look consistent and reproducible. Here you may be doing something you are not aware of that is causing all your measurements to be off the same amount. For example, if you were not aware that a piece of your ruler had been cut off and now starts at 2" instead of 1", all your measurements would be one inch too long. This is a systematic error because all your data is affected the same amount, and in the same direction. One way to check for systematic errors is to run experiments of a different design that should give the same answers. Scientists often do different kinds of experiments to cross check their results. Another way to locate errors is to have an independent investigator repeat your experiments. Others should get the same results you did.

Linked Variables

Your results can be invalid if your variables are not independent of one another, and you have not noticed this. Variables are independent if they produce their effects separately from each other. In other words, changing one variable does not affect changes produced by another variable.

WHAT IF MY SCIENCE PROJECT DOES NOT WORK?

No matter what happens, you will learn something. Science is not only about getting "the answer." Even if your experiments don't answer your questions, they will provide ideas that can be used to design other experiments. Knowing that something didn't work, is actually knowing quite a lot. Unsuccessful experiments are an important step in finding an answer. Scientists who study extremely complex problems can spend a lifetime and not find "the answer." Even so, their results are valuable. Eventually, someone will use their work to find the answer. Are you that person?

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And the students of the 1995-1996 Research Pilot class at Vines High School