CONDUCTING A RESEARCH PROJECT: FOR THE YOUNG SCIENTIST

Background

The purpose of this article is to assist the beginning investigator who is planning a science project for a class or who wishes to participate in the local science fair. Planning and conducting a science project can be a very exciting and rewarding way to actively participate in science. It may also help you to discover some career opportunities for your future.

The scientific investigation is a way to learn by direct experience. The student research projects outlined in this workbook are intended to be a source of ideas for problem solving, i.e. identifying problems, making decisions and evaluating out comes. They provide an opportunity to extend the learning experience beyond the printed word of the textbook, which often contains the organized product of science, into the process of science.

Due to the uniqueness of each investigator, situation and problem to be solved, there is no single scientific methods, or process of science, or method of inquiry to be used for all experiments. The steps outlined below are provided as a guide for you to follow using the traditional methods of an experimental scientist.

Identity Problem

The authors of the projects in this workbook have identified problems in the food, agricultural and natural resource sciences which can be investigated. There are two important considerations for you to consider in selecting a problem to investigate. First, it should be of interest to you. This will not only make learning more enjoyable but can also lead to an awareness of careers.

The problem should also be narrow enough to be realistic in terms of the definition of the problem to be investigated and the time it will take you to complete the experiment. A topic such as animal nutrition is too general. However, the impact of nutrition on body composition in the pig might be a very realistic study.

After reading through some projects in this workbook, you may find it helpful to modify a project to meet your interests, timetable and materials needed.

Formulated Hypothesis

After you have identified a problem and written a description of the problem, then you are ready to formulate a tentative hypothesis by reasoning and making assumptions. The formulation of a hypothesis is one of the distinctive characteristics of experimentation as opposed to a demonstration. The hypothesis is a statement to be proved or disproved.

To develop the hypothesis, start by asking questions about the problem.

For example: Does temperature affect seed germination?

Then, rephrase the question into a hypothesis. It should predict a possible result and should be phrased as a testable statement. Often the hypothesis is a scientific guess as to what the investigator believes the outcome will be. For example: Seeds germinate faster at higher temperatures.

After a tentative hypothesis has been formulated, you should next perform a search of the literature on this problem. Reading about the results of other investigators may give you an idea for modifying your hypothesis. A precisely stated hypothesis will also help to suggest how to design the investigation.

Library Research

The primary purpose of the library research phase is to gain further insight into your problem by reviewing the results of previous investigations on this topic or related topics. The references at the end of an article can lead you to more information. You can also obtain ideas about the methodology or investigation design which has or has not worked for other investigators, the statistical techniques they used to analyze their data and the ways in which data is presented in tables and graphs.

Make reference cards on each book, article or other source you consult. Also take notes, either direct quotes or as a paraphrase, as you read the literature. You will need this information to write the background for your report.

Design Investigation

This step in the experimentation process if often called "the methodology". It should be the design or method describing exactly how you plan to test the hypothesis. The design should be written in enough detail that another investigator can read it and be able to duplicate your experiment. There are several types of experiment designs ranging from simple controlled experiment to the survey technique used to sample or collect data from a group. You will need to select a design for your investigation that best tests your hypothesis.

The design of your experiment should anticipate the data you will need to collect and the statistical analysis you will use to accept or reject your hypothesis. This will help determine the procedure (how collected, when, etc.) the type of measurement (height, weight, units to be used, etc.) and the format of the tables (column headings) you will use to collect the data.

The method of testing the hypothesis is important in an experiment because normally there are numerous variables involved. Therefore, the simple controlled experiment is recently used in biological research to attempt to assure that only the variable being tested is affecting the results. The investigator attempts to eliminate all other variables by running in parallel two or more experiments identical in every respect except one so that whatever differences are observed will be due only to the single, known variable. The intent is to change one variable at a time (called the independent variable) in order to observe any change or outcome (called dependent variable).

In a simple controlled experiment, the design should include a "control group" and an "experimental group". For example, assume that you wish to determine the effect of nitrogen fertilizer (an independent variable) on the growth of young bean plants. If you plant some beans, fertilize each plant with 1 gram of ammonium nitrate fertilizer (N) and the beans grow well, you might conclude that the N helped them grow. But without a "control" of 0 grams of N, you have no way of knowing whether the beans might have grown the same amount without the nitrogen. You need a group of bean plants as a control for the purpose of comparison. Now suppose you wish to determine the effect of different amounts of N on the growth of young bean plants. You plant 120 beans, fertilize 30 plants with 1 gram of N, 30 plants with 2 grams of N and 30 plants with 4 grams of N. These are the experimental groups. Thirty plants should also receive 0 grams of N. This is the control group.

The design of your experiment should try to anticipate sources of experimental error which could bias your data. In the bean experiment above, variables such as the amount of water given each plant, differences in soil in individual pots, and the amount of light and temperature could influence the growth. In a controlled experiment, all of these variables must be as identical as humanly possible for both the experimental and control groups. For example, if you planted some small, cracked bean seeds for the control group and all the other seeds planted were large and undamaged, error has probably been introduced into the experiment. Error could also be introduced if one experimental group of plants was located nearer a window than the others. Labeling and randomly assigning a location to each pot in which a bean seed has been planted would reduce this source of effort. This is called randomization and this technique should be used whenever possible to remove systemic error.

The controlled experiment should also be designed to have enough subjects in both the control group and experimental groups that you can have confidence in your results. You will have more confidence in your conclusions if you have 30 bean plants in each group rather than one. You need to make your groups large enough to rule out the possibility of normal, individual differences. If you need help in determining the size of your groups, seek the advice of a professional trained in statistical analysis.

Replication, or repeating the experiment, also serves to diminish the error in test results. If time permits, it would be good experimental design to repeat the experiment two or three times. If your experiment involves the use of laboratory animals, there is both a scientific and ethical responsibility for the humane care and general welfare of these animals. The article titled "Care and Use of Laboratory Animals" contained in this workbook provides references for guidelines and recommendations. Do not let the guidelines discourage you from investigations involving experimental animals. Nothing in the guidelines is intended to limit an investigator's freedom - indeed, obligation — to plan and conduct animal experiments in accord with scientific and humane principles.

Write Proposal

Up to now, you have been planning your experiment. You have identified a problem, formulated a hypothesis, read the literature and decided upon the design of your investigation. Before you begin your experiment, you should write out a statement about each of these areas in the form of a mini-proposal (2-3 pages). Share it with your teacher or another professional and ask for suggestions to improve your experiment. If you plan to contact faculty at a university or researchers in industry for assistance, send the a copy of your mini-proposal. It will make it easier for these busy people to respond to your questions.

Collect Data

Any measurement in collecting data is subject to sources of error. The object in this phase of the investigation is to anticipate where those sources might be in the experiment and to attempt to minimize the error. The data should be entered into tables which you devised in the investigation design. You should record the data in a notebook and also record other non-statistical observations about your control and experimental groups. The latter observations may later help you explain a particular result you did not expect. After the data is collected, you are ready to analyze it in an exact and impartial way. Estimators of central tendency (the mean or average, median and mode) are generally the most useful all-around statistics to describe biological variables. However, by itself, the mean of a control or experimental group leaves much to be desired because it is strongly influenced by a few extreme values. A measure of the degree of dispersion about the mean of the group is needed. One such measure you may wish to compute is the standard deviation. There are other statistical tests which may apply to your data to help you interpret whether the mean of the data for an experimental group is significantly different from the mean of the data for the control group. It is suggested that you consult some of the basic statistics books in the library or a professional trained in statistics if you need help with the standard deviation or a test of significant difference between the means.

Draw Conclusion

This step in the investigation is where you decide to accept or reject your hypothesis. The analysis of your data will either support your hypothesis or it will not. This must be stated in your conclusion. Be cautious that your conclusion is not a new hypothesis. In an experiment, the investigator attempts to draw conclusions about the general population based upon data taken from a sample. You conclude or infer from the specific to the general. Let's return to the bean experiment mentioned earlier. You collected data on a sample of 30 beans in one experimental group to which N (a variable) was applied. You can only infer that all bean plants (the total population) will have the same response. The probability of this would not have been very high if the sample size was only ten bean plants. But your confidence in concluding that this result will happen to the total population is much higher with a sample of 30 bean plants. Hence, it is important for you to draw conclusions about the relationship among the variables but to do so within the limits of the data. Are your conclusions valid? Is it possible the results you obtained could have been caused by some other variable?

Write Report

Now you are ready to switch from being a investigator to becoming a scientific author. Your research project should be presented in a concise, written report. The following is a conventional form for a formal (scientific) report.

Supplements that precede your report:
-cover
-title page
-abstract (a mini-report)
-table of contents

-table of figures (as needed)

The report:
-introduction (including background, statement of problem and hypothesis)
-experimental design
-conclusions
-references

Supplements that follow your report:
-glossary (as needed)
-appendixes (as needed)

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