INTRODUCTION TO EXPERIMENTAL DESIGN

Experimental Design is an event, which tests a team's ability to design, conduct, and report the findings of an experiment actually conducted on sight. The event supervisor will assign a topic or question and provide the materials to be used as well as an outline similar to the scoring rubric for recording/reporting the experiment. Students will design an experiment that is simple in design and involves only one independent variable and one dependent variable. Multiple trials will be made and a report will be prepared within the event time period, which is about 50 minutes.

The **parts of an experiment** are as follows:

PROBLEM: A statement that defines the topic of the experiment and identifies the relationship between the two variables. Be specific enough to allow the design of an experiment. It should generalize the factors being tested as" The effect of the (independent variable) upon the (dependent variable)."

HYPOTHESIS: A statement that predicts the outcome of testing the relationship between the independent variable and the dependent variable as specified in the problem. Be sure to include your rationale for this prediction.

VARIABLES: Environmental factors or conditions which can change.

Independent Variable is the factor being purposely changed or manipulated.

Dependent Variable is the factor, which responds to the change in the Independent Variable. Its response is measured as data.

Constants (controlled variables) are all other factors, which are not manipulated during the experiment. These are often potential independent variables for future experiments.

EXPERIMENTAL CONTROL (STANDARD OF COMPARISON): The component in which the independent variable is not changed or manipulated. It is used to verify that from trial to trial everything is kept the same and that the change in the independent variable is actually causing the response in the dependent variable.

MATERIALS AND PROCEDURE: A recipe for conducting the experiment. It consists of a list of materials/equipment followed by step-by-step instructions. These instructions must be specific enough to allow the experiment to be repeated exactly the same way each time it is conducted. Specify what type data should be collected during the experiment in order to measure the response of the dependent variable.

QUALITATIVE DATA: Observations or descriptions of things noticed with the senses during the course of the experiment and any data based on a nonstandard scale. Observations may pertain to things that happen relative to the dependent variable as well as those are not directly related to the dependent variable, the procedure, or and things that went wrong during the experiment. These types of observations may assist you in identify errors and evaluating the results. Qualitative data is usually categorized by factors such as color, texture, shape, size, and behavior and is organized into a table, diagram, or flow chart. You may draw pictures to show what you observed. Qualitative data may be as important as the measurements in evaluating the results so do not under estimate their worth.

QUANTITATIVE DATA: Data that is based upon measurement and the presentation of this data. When organizing data for analysis, use visual tools as data tables, graphs, diagrams or flow charts. Be sure to thoroughly label all graphs, diagrams or flow charts.

Measurement: A measurement requires both magnitude (how much) and a unit. Examine the instrument to be sure you know its capacity and the value of the numbered graduations or increments as well as the unnumbered ones. Be sure to select the appropriate instrument for the proper degree of accuracy. When you are measuring liquids in a cylinder or pipette, remember to read the bottom of the meniscus curve.

Data Tables: Use data tables to organize data as it is collected. Be sure all data raw data is given and that the correct significant figures are used and units are included. Also be sure all appropriate labels are included. Provide another condensed table with the most important data.

Graphs: When graphing, remember that the independent variable goes on the horizontal or X - axis while the dependent variable goes on the vertical or Y- axis. To scale or number the axis of a graph so it will always fit the grid, use the following formula: High value - Low value (use zero if you plan to start numbering by zero) divided by the number of spaces on that axis. Always round up. Begin numbering with your lowest value and go up by your calculated graduation. Be sure to include all appropriate labels.

STATISTICAL ANALYSIS OF DATA:

Measure of Central Tendency: A value at the center of the data set. It can be measured as the mean or average, the median, or the mode.

Measure of Variation: For qualitative data, a frequency table or histogram can be used. For quantitative data, the range and standard deviation should be used.

Regression Analysis: Using an equation or graph to show the relationship of variables. Finding the line of best fit is often used.

Percent Error: Another common form of statistic analysis.

ANALYSIS OF RESULTS: Evaluate the qualitative and quantitative data. How do the results of your various trials compare? What was learned from this experiment? What trend was established? Does the data support your hypothesis? Why or Why not?

POSSIBLE EXPERIMENTAL ERRORS: Any human mistakes that were made and any experimental errors that became evident. What effect did these errors and/or mistakes have on the qualitative or quantitative data. What went wrong during the experiment and how should the experiment have been done differently to avoid these problems in the future?

CONCLUSION: Restate the hypothesis and summarize the major results. Explain why the results did or did not support the hypothesis. Include what was learned and any unexpected results.

RECOMMENDATIONS FOR FURTHER INVESTIGATION AND APPLICATIONS: Recommend modifications of the experiment design or procedure. For future testing, give suggestions for refinement of your hypothesis based upon your data. Include other aspects of the general topic that should be considered for future investigations in order to better understand the general topic or question. Finally give practical applications for the principles obtained from the experiment.

REPORT: The report will be written. Use the outline provided by the event supervisor to organize your report. It is similar to the rubric that will be used to evaluate your report.

EXPERIMENTAL DESIGN - SAMPLE SCORING RUBRIC

Statement of Problem: Experimental problem: Statement of problem should not have a yes or no answer. It should be specific to the experiment being conducted and is not the same as the assigned question/topic area**.**

_____ Not a yes/no question
_____ Statement narrows down topic area (implies a specific experiment)
_____ Generalized variables included
_____ Problem is clearly testable

Hypothesis: Including **prior** knowledge that contributed to hypothesis
_____ Statement predicts a relationship or trend
_____ Statement gives specific direction to the predictions(s): A stand is taken.
_____ Prediction includes both independent and dependent variables
_____ A rationale is given for the hypothesis

Variables: The variables should be operationally defined.

Independent Variable: Factor being manipulated (**only one**)
_____ IV correctly identified
_____ IV operationally defined
_____ At least three levels of IV given

Dependent Variable: Factor which responds (**only one**)
_____ DV correctly identified
_____ DV operationally defined

Constants: (Controlled Variables) Factors that are **purposefully kept the same**
_____ One CV correctly identified
_____ Two CVs correctly identified
_____ Three CVs correctly identified
_____ Four CVs correctly identified

Experimental Control: **(Standard of Comparison)**
_____ A SOC is identified
_____ The SOC makes logical sense for the experiment being done
_____ Reason given for why response is SOC

Materials and Procedure: Including Diagrams
_____ All materials used are listed properly (no extras)
_____ Materials listed separately from procedure
_____ Procedure well organized
_____ Procedure is in a logical sequence
_____ Enough information is given so another could repeat procedure
_____ Diagrams used
_____ Repeated trials

Qualitative Observations During Experiment & Summary of Results
_____ Observations about results given
_____ Observations about procedure / deviations
_____ Observations about results not directly relating to DV (extra information)
_____ Observations given throughout course of experiment

Quantitative Data

Data Table: (Including Use of Significant Figures Division C)
_____ All raw data is given
_____ All data has units
_____ All data reported using correct significant figures
_____ Condensed table with most important data included
_____ Table(s) labeled properly
_____ Example calculations are given

Graph(s):
_____ Appropriate type of graph used
_____ Graph has title
_____ Graph labeled properly (axis/series)

_____ Units included
_____ Trends in data are represented
_____ Appropriate scale used

Statistics:

Div. B: Including the Average and other relevant statistic such as median, mode, range, or drawn in line of best-fit

Div. C: Including a measure of central tendency (mean), a measure of variation (range or standard deviation), regression analysis (line of best-fit), and any other relevant statistics

_____ Measure of central tendency
_____ Measure of variation
_____ Regression analysis
_____ Other appropriate statistic used

Analysis of Results: Interpretation

_____ All data discussed: 'What it is'
_____ All data interpreted: 'What it means'
_____ Unusual data points pointed out
_____ Unusual data points explained
_____ Trends in data are pointed out
_____ Trends are interpreted/explained
_____ Statistics are explained
_____ Enough detail is given to understand data
_____ Response is clear and concise
_____ All statements are supported by the data

Possible Experimental Errors: Human mistakes and Experimental Errors (Systematic or Random)

_____ Possible reasons for errors are given
_____ Important information about data collection given
_____ Effect errors had on data discussed

Conclusion: Include why your results did or did not support the hypothesis

_____ Hypothesis is evaluated according to data
_____ Hypothesis is re-stated
_____ **Reasons** to accept/reject hypothesis given
_____ All statements are supported by the data

Recommendations for further experimentation: Recommendations for Further Experimentation Based on Your Data & Practical Applications

_____ Suggestions for improvement of specific experiment are given
_____ Suggestions for other ways to look at hypothesis given
_____ Suggestions for future experiments given
_____Practical application(s) of experiment given

Note: **The experiment should be simple in design and have only one independent and one dependent variable**.

I hope this handout is helpful in preparing your students. Comments or new ideas are always welcome.

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There is a new training manual entitled “A Coaches Handbook for Experimental Design” available from the Science Olympiad National Office. It contains lessons for use in the classroom and with your team as well as previous tournaments.

There are also training manuals for other events and video tapes for many building events. The order form for all training guides and video tapes is available at http://soinc.org/tguides.htm