Experimental Design 2007

Dr. Bill Wellnitz
Augusta State University
(706) 731-7993
wwellnit@aug.edu

Team members: 3

a. one who can quickly write clear, concise statements with legible handwriting
b. one or two who can actually do things well in a lab
c. at least one who can think on feet, quickly, and sometimes outside the box

members of this team must get along and be able to reach a uniform consensus about things

What follows, represents an ideal situation. Unfortunately many sites will give vague descriptions of the nature: "Design an experiment that can be tested.". Students may get merely a blank sheet of paper.

1. Many people, but not all, use the attached scoring rubric. It is useful to make the kids aware of it, so they can see how some things are scored. Spend some time going over this rubric with kids.

2. The problem can be anything. When I run this, I prefer to give the students some parameters that may be tested and also specific places to put certain answers. (see next handout) This type of organization makes for easier grading. Not all event coordinators will do this however. Last year at national students were given many sheets of blank paper and told to design an experiment that would show that powdered yeast was in fact alive.

Students should number statements, etc as much as possible within section. This makes for easier grading.

3. The problem when stated should not have a yes or no answer.

4. The hypothesis should be testable and should allow for the differentiation between or among different hypotheses. It is probably helpful to state how variables will come into play: If yeast are alive, they should give off gas when placed in water as they start to grow. The amount of gas given off should increase as the temperature of the water increases, but only up to a certain temperature. Higher temperatures will kill living things.

At some point as students are designing an experiment, they should strive for something that can be repeated at least twice. The fact that the experiment was repeated should actually be mentioned in a couple places: procedure, data analysis, and conclusions.

5. It is essential that kids know difference between independent and dependent variables
Independent: that parameter that the experimenter varies
Dependent: the parameter that is measured
Controlled: those things that are kept constant throughout expt, for example, the amount of light in the room, temperature of room, etc.

When they state the independent and dependent variable(s), they should also state the specific units of variable (operational variable)

Ex: Independent variable: diameter of tube; we will use diameters of 1/8", 1/4", 3/8" and 1/2"
Stating the operational variables after the ind and dep may be worth an extra point.

Caution: do not fall into the trap of telling students that time is always the independent variable (I have numerous cases in which the above was actually stated). In some expts, you are actually determining how long it takes to do something under different conditions.

6. Students should define the control, but be aware that not all expts have a control (standard of comparison). If the expt does not have a control, students should say so and also say why there is no control. If a control is used, they should say why it is a control.

Examples
Identify various variables in the following expts:

a. Amount of gas given off after yeast is put into water of different temps.
b. The time required to empty a container using different size tubing.

7. **List** materials separately, even if the section is headed material and procedures.

cup	Stop watch
200 ml beaker	200 ml graduate
water from faucet	25 ml graduate

Do not say we used a cup, a 200 ml beaker, etc. Although this approach may be acceptable, first format is easier to grade and hence may be worth an organizational point, especially in a tie breaker.

8. Procedure: a section where many students typically lose points. They often omit things that they did, or do not state what they did clearly. Remember, the purpose of this section is to make certain that some one else can repeat the expt (even if in real life many scientists often omit steps so some one else CANNOT repeat their work.)

Drawings may be useful to show the actual experimental set up. If a drawing is used, it should be clear, simple, and all parts must be clearly labeled.

9. Many students do not give some brief qualitative observations; they should: At the start of the expt, all the dye was at the top of the tube. As time progressed, the dye began to spread out and move toward the bottom of the tube. We measured the rate at which the dye traveled.

10. Recording data:

usually in a table
the table should be labeled with a title
all columns in table should have a heading(with in the table)
all data should be inside the table, not outside
units should be listed; often in the column heading is sufficient

National rubric has points for calculations. It may be helpful, and worth an extra point to provide one sample calculation outside/below the table etc. Ex: if one column is for average, below table should be sample average calculation, actually set up the old fashioned way!

11. Graphs:

a. Should have title, above or below the graph, preferably above
b. Each axis should be labeled, and units should be defined or mentioned
c. Make sure that spacing between numbers on scale is constant
d. Numbers on axes should increase as one moves to the right or up
e. Type of graph should be appropriate for the expt. Not all expts require a line graph; some are better suited for a bar graph, and others a pie graph.
f. Data points on graphs should not be dots but rather open circles, xs, open squares etc.
g. As many points as possible should be connected if need be. It is OK to exclude an outlying point if this item is discussed in the discussion section

For C, students may want to use statistical programs on some calculators, especially regression for line of best fit. If calculating averages, it might be useful to run standard deviation program and plot point plus error bars. If graph does not appear to be straight line, trying to develop a 2^{nd} order or higher equation may be helpful.

12. Data analysis: almost always the weakest part of the test. More than one sentence is almost always required. Students should be as descriptive as possible. If the data give a curved line, it is not enough to say as a increases, b increases. It should be mentioned that it is probably exponential. Adding a sentence as to why the graph is exponential is often worth another point. Students should call attention to any unusual or outlying points and try to explain them or at least say why they were not used. If there were no unusual points, this should probably be mentioned as well. It may be helpful to refer grader to the figure: the graph shows ....

13. Error---many students can point out where error may occur, but this is usually done in vague terms. It should be explained how the sources of error will impact the data: *example:* Since some of the balls were not exactly spherical, their rate of movement will be less than that of a sphere.

14. Conclusion: restate hypothesis and then state whether the results support or refute the proposed hypothesis. If they refute the hypothesis, then propose a new hypothesis.

15. Future: briefly describe other expts that can be done; give expected general result
Provide any potential applications of this expt, or say why the conclusions are important.

CLASSROOM ACTIVITIES:

1. Numerous situations in which you ask what are/were the variables. Use items in the news.

2. Make students draw graphs of all sorts of things (and draw by hand, not with computer!). Take numbers from the paper and have students make a graph.

3. Have students turn in lab reports for labs (more time to grade!)

4. After a lab, discuss sources of error, implications of error, conclusions of expt. maybe sometimes have them submit this.

5. After kids have done a couple labs, try to get them to write procedures themselves. This should be done a day ahead of time. Then have another student in class try to follow the directions (good exercise for write it do it as well) without asking the writer any questions. Can sometimes be done as a demo.

6. Other activities for following/giving directions:
   a. Have one member write directions on how to get to a certain room in school. Another student then tries to find room.
   b. Have one student draw map with no words on map.
   c. One student gives written or oral directions on how to draw an asymmetric object (see handout)

A couple sample scoring rubrics follow; more can be found by doing a search for “experimental design rubric”

Experimental Design
Division C Rubric 2003

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

2. 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

3. Variables

   Independent Variable
   - _____ IV correctly identified
   - _____ IV operationally defined
   - _____ At least three levels of IV given

   Dependent Variable
   - _____ (2) DV correctly identified
   - _____ DV operationally defined

   Controlled Variables
   - _____ One CV correctly identified
   - _____ Two CVs correctly identified
   - _____ Three CVs correctly identified
   - _____ Four CVs correctly identified

4. Standards of Comparison
   - _____ A SOC is identified
   - _____ The SOC makes logical sense for the experiment being done
   - _____ Reason given for why response is SOC

5. Materials and Procedure
   - _____ All materials used are listed properly (no extras)
   - _____ Materials listed separately from procedure
   - _____ Procedure well organized
   - _____ Procedure is in a logical sequence
   - _____ (2) Enough information is given so another could repeat procedure
   - _____ Diagrams used
   - _____ Repeated trials

6. Qualitative Observations
   - _____ Observations about results given
   - _____ Observations about procedure / deviations
   - _____ Observations about results not directly relating to DV(extra info)
   - _____ Observations given throughout course of experiment

7. Quantitative Data

   Data Table
   - _____ 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 (axes/series)
   - _____ Units included
   - _____ Trends in data are represented
   - _____ Appropriate scale used

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

8. Analysis and interpretation of data
   - _____ 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

9. Possible Experimental Errors
   - _____ Possible reasons for errors are given
   - _____ Important info about data collection given
   - _____ Effect errors had on data discussed

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

11. Recommendations for further experimentation
    - _____ 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

School________________ Team members____________________________

Possible points________ Team score______ Place________

Experimental Design
Division B Rubric

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

2. 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

3. Variables

    Independent Variable
    - _____ IV correctly identified
    - _____ IV operationally defined
    - _____ At least three levels of IV given

    Dependent Variable
    - _____ (2) DV correctly identified
    - _____ DV operationally defined

    Controlled Variables
    - _____ (2) 1 CV correctly identified
    - _____ 2 CV correctly identified
    - _____ 3 CV correctly identified

4. Standards of Comparison
    - _____ A SOC is identified
    - _____ The SOC makes logical sense for the experiment being done
    - _____ Reason given for why response is SOC

5. Materials and Procedure
    - _____ All materials used are listed (no extras)
    - _____ Materials listed separately from procedure
    - _____ Procedure well organized
    - _____ Procedure is in a logical sequence
    - _____ (2) Enough information is given so another could repeat procedure
    - _____ Diagrams used
    - _____ Repeated trials

6. Qualitative Observations
    - _____ Observations about results given
    - _____ Observations about procedure / deviations
    - _____ Observations about results not directly relating to DV(extra info)
    - _____ Observations given throughout course of experiment

7. Quantitative Data

    Data Table
    - _____ All raw data is given
    - _____ All data has units
    - _____ Condensed table with most important data included
    - _____ Table(s) labeled properly: titles, units, headings
    - _____ Example calculations are given
    - _____ Appropriate statistics are given (example: average)

    Graph(s)
    - _____ Appropriate type of graph used
    - _____ Graph has title
    - _____ Graph labeled properly: (axes/series)
    - _____ Units included
    - _____ Appropriate scale used
    - _____ Trends in data are represented

8. Analysis and interpretation of data
    - _____ All data discussed and interpreted
    - _____ Unusual data points commented on
    - _____ Trends in data explained and interpreted
    - _____ Enough detail is given to understand data

9. Possible Experimental Errors
    - _____ Possible reasons for errors are given
    - _____ Important info about data collection given
    - _____ Effect errors had on data discussed

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

11. Recommendations for further experimentation
    - _____ 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 give

Experimental Design

Emory University
14 April 2001

School number_____

Do not open this booklet until you are told to do so!

Please clean up your station before leaving. Teams that do not clean up will receive a 15 point penalty.

A **siphon** is a device that allows that transfer of liquid from one container to another by using a tube. The reservoir (starting container) must be higher than the receptacle (finishing container). To create a force to move the liquid, the tube must be filled with liquid before placing it in the reservoir. Place the tube near the faucet and fill it with water. **DO NOT FILL THE TUBE BY SUCKING !!!! ANY TEAM SEEN SUCKING THE TUBE WILL BE PENALIZED 15 POINTS.**

Several factors may influence the rate at which liquid is transferred: the height difference between reservoir and receptacle, the volume of liquid in the reservoir, the diameter of the tubing used, and the temperature of the liquid transferred.

Your task is to design an experiment that tests only one of the above parameters. All of your statements, etc. must be placed in the indicated location on the following pages. Most sections contain numbers for listing things. Not all the numbers listed need be used; they are there partly to aid in grading. Please write legibly; illegible answers will receive no points.

Materials available at each station:

2 feet pieces of tubing of 1/32”, 1/16”, 1/8” 3/16” diameter
meter stick
stop watch
thermometer
Styrofoam cup
10 mL graduated cylinder
250 mL Erlenmeyer flask
ringstand and clamps
Large container of cold water
Large container of hot water

Many experiments have control groups and require replication. These considerations may or may not be appropriate to this experiment.

1. STATEMENT OF PROBLEM

2. HYPOTHESIS

3. VARIABLES

   A. INDEPENDENT VARIABLE(S)
      1.

      2.

      3.

   B. DEPENDENT VARIABLE(S)
      1.

      2.

      3.

   C. CONTROLLED VARIABLE(S)

      1.

      2.

      3.

      4.

4. STANDARDS OF COMPARISON (CONTROL)

5. MATERIALS

   1.

   2.

   3

   4. etc

   AND PROCEDURE
   1.
   2.
   3.

6. QUALITATIVE DATA

7. QUANTITATIVE DATA (GRAPH, TABLE, ETC)

Raw data

Graph of results

8 ANALYSIS OF DATA

9. POSSILBE EXPERIMENTAL ERROR(S)

    1.

    2.

    3.

    4.

10. CONCLCUISON(S)

    1.

    2.

11. RECOMMENDATIONS FOR FURTHER STUDY

1.

2.

3.

4.