

Experimental Design 2007
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- 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 2nd 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 prediction(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 prediction(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. POSSIBLE EXPERIMENTAL ERROR(S)

- 1.
- 2.
- 3.
- 4.

10. CONCLUSION(S)

- 1.
- 2.

11. RECOMMENDATIONS FOR FURTHER STUDY

- 1.
- 2.
- 3.
- 4.