A Closer Look at *Experimental Design Topics*

" *Blocking* is used to control the factors you
can see;

Randomization helps balance the ones you
cannot see."

Richard L. Scheaffer
Chief Faculty Consultant
1997-1999

NCSSM Statistics Leadership Institute 2001

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Introduction

Popular textbook coverage of and teacher experiences with topics in experimental design vary widely. Experimental design is included in the AP Statistics curriculum and every AP exam through 2001 has included a free response question on experimental design.

This packet was developed to provide additional experimental design resources for teachers. The material in this packet includes the following:

- a discussion of the concepts covered in each of the experimental design questions that appeared on the AP Exams from 1997 through 2001 and links to the web sites where these questions and their ancillary materials can be found
- a list of textbooks that are good references for teachers needing to learn more about the topic of experimental design
- links to the AP Statistics *discussion list archives* where extensive dialog related to these questions is stored
- links to related activities that are available for classroom use

The matrix below summarizes the AP Exam questions and their related concepts:

First Five Years of Experimental Design AP Examination Questions

Year	Question	Name	Main Concepts	Side Issues
1997	5	Fishtank	Blocking	Randomization
1998	3	Butterflies	Randomization	Factors Levels
1999	3	Apples	Observation vs. Experiment Confounding	Samples of Convenience Scope of Inference
2000	5	Cholesterol	Completely Randomized Experiment Blocking Double-blind	
2001	4	Fruit Trees	Blocking Randomization	

For More Information on Experimental Design

AP Statistics discussion list archives: http://forum.swarthmore.edu/epigone/apstat-l

The following terms are often used in discussions on experimental design. Extensive discussion on these and other topics can be found at the above-mentioned web site.

Block
Completely Randomized Design
Confounding
Control Group
Double Blind
Experiment
Experimental Unit/Subject
Explanatory Variable
Homogenous
Matched Pairs
Observational Study
Placebo
Random Assignment
Randomized Block Design
Replication
Response Variable
Scope of Inference
Single Blind
Test of Homogeneity
Test of Independence
Treatment

When searching the web, you might be particularly interested in items contributed by current and former members of the AP Statistics Development Committee and Chief Faculty Consultants* (1997-2002).

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John J. Diehl
Fred C. Djang
Katherine Taylor Halverson
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1997 Free-Response *Question 4*

Synopsis of Question

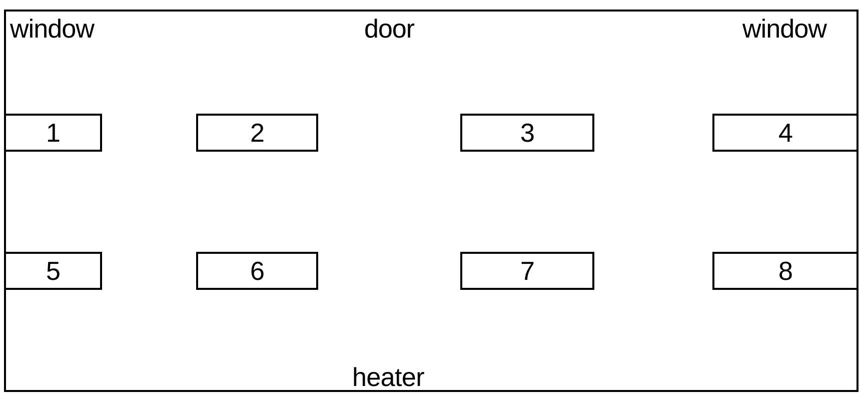
The problem stem described a situation where researchers wanted to compare the weight gain for salmon raised on an old type of food with their weight gain using a new type of food. The fish had already been randomly assigned to tanks, but the tanks were located in areas where room temperature varies greatly. Students were told to design an experiment to compare the weight gain of the salmon using the two types of food while taking into account the differences in temperatures in the room.

Links to College Board Resources

Full text of this question and ancillary information is available in the 1997 AP Statistics Released Examination booklet from the College Board.

Discussion of Concepts

This question tests the students' understanding of blocking and random assignment of subjects to treatment groups. The response variable for the experiment is weight gain, and the explanatory variable is food type. The blocking variable is room location as it applies to room temperature.



The problem stem describes a room with considerable temperature gradient. It states that the side of the room at the top of the accompanying drawing is much colder than the side at the bottom of the drawing. The diagram also suggests the fish tanks' proximity to the door, heater, and windows could affect the temperature. One could reasonably conclude that the growth rate of salmon might be affected by these conditions. Because there are only two treatments, blocks as small as 2 tanks each are permissible. This allows the blocks to incorporate north/south differences as well as interior/exterior locations in the room. The pairings that best account for temperature differences in the room are (1,4), (2,3), (5,8), and (6,7). Pairs (1,4) and (2,3) are on the north (colder) side of the room, while pairs (5,8), and (6,7) are on the south (warmer) side of the room. Pairs (1,4) and (5,8) are closest to the east west walls while (2,3) and (6,7) are located in the center of the room. These pairings could account for possible drafts from windows or open doors. Remember it is always important to create blocks that are homogenous with respect to your blocking variable.

Within each pair, randomly assign the new food type to the salmon in one tank while giving the old food type to the salmon in the other tank. You may either randomly assign tanks to treatments or treatments to tanks. It does not make a difference. There are numerous ways to make random selections. Some of those will be mentioned at the end of this document. Remember, whatever randomization method you use and whatever order you select, be sure that both food types have an equal opportunity to be assigned to the first tank in the pair, then the other food type is assigned to the remaining tank. Additional variability caused by factors other than food types are addressed through the randomization process so the observed variability should be due to differences produced by the food types.

At the end of the six-month period, each salmon's weight gain is determined. For each pair, the difference in weight gain is calculated, consistently subtracting treatment one salmon's weight gain (old food) from treatment two salmon's weight gain (new food) or vice versa. These differences are analyzed to see if the mean is significantly different from zero.

Additional Notes

This random assignment can be done using a coin flip where heads are reserved for one food type and tails for the other. It could be done using a die where even numbers on a roll are associated with one food type and odd numbers the other. It could also be done using random number tables or a random number generator on a calculator. The important idea is that each tank in the pair has an equal opportunity to receive either food type.

Additional Resources

A student activity that illustrates the effects of blocking can be found as **Attachment 1** at the end of this document.

1998 Free Response *Question 3*

Synopsis of Question

The problem that became known as "The Butterfly Problem" involved marking butterflies in one of six wing locations in order to determine whether there was any difference between the location of the mark and the success rate in migrating. To do this 3600 butterflies were to be marked, released, and the number of successful migrants with each marking location was to be recorded at the end of the migratory path.

Links to College Board Resources

The link to the College Board Web Site that contains question 3 and ancillary information is http://www.collegeboard.org/ap/statistics/frq98/index.html

Discussion of Concepts

This question tests students' understanding of methods of random assignment of *treatment* (marking location) to *experimental units* (butterflies).

In this experiment, the experimental units (units to which a treatment is applied) are butterflies, the explanatory variable is marking location and the response variable is success in arriving at the destination. "The purpose of random assignment is to make the groups approximately equal in all respects except for the explanatory variable, which is purposely manipulated." (*Mind on Statistics,* Utts and Heckard, 2002, p. 61). Stated another way, "randomization can be effective in evening out the effects of extraneous variables." (*Statistics and Data Analysis,* Peck, Olsen, and Devore, 2001, p. 30).

Part A asks what method you would use to assign the marking locations (treatment) if you want to have exactly 600 experimental units (butterflies) with each treatment. The two tasks are randomizing and assigning exactly 600 experimental units to each treatment.

An example of a randomization scheme is to have 600 slips labeled A, 600 slips labeled B, and so on, in a hat. Select a butterfly, draw a slip out of the hat (without replacement) and label the butterfly accordingly. There are other reasonable randomization procedures that will accomplish these goals.

Systematically assigning marking locations to successive butterflies in groups of 6 is also acceptable (Marking location A to the first butterfly, B to second, and so forth). In this case you are "randomly selecting" a butterfly and then systematically assigning it to a treatment rather than randomly selecting a butterfly and randomly selecting a treatment.

It is not sufficient to capture the first 600 butterflies and assign them to a single treatment, capture the second 600 and assign them to another treatment, and so on until all six treatments have been assigned 600 units. If all of the butterflies captured in a group have a common attribute, such as slowness, then another variable such as speed of the butterfly might not be balanced across all treatments.

In the second part of the problem, the assignment of treatments to units is to be independent from one unit to the next, and each location is to be assigned with a probability of 1/6 each time. In this scenario, some device that will generate equally likely random events A – F is necessary. One possibility is to toss a die and assign 1 to A, 2 to B, and so on, ending with 6 to F. A unit is captured, the die tossed, and the corresponding treatment is assigned to the unit. In this case it is unlikely that each of the six treatments will have exactly the same number of units assigned. Note that a random digit table could also be used by assigning 1 to A, 2 to B, 3 to C, 4 to D, 5 to E, and 6 to E. Digits 7 – 9 and 0 could be discarded.

The third and fourth parts of this question have to do with the type of analysis that is appropriate. In both cases the null hypothesis states there is no difference in the proportions that successfully migrate for each marked location on the wing. The alternate hypothesis is that at least one of the marking locations resulted in a different proportion of successful migrants. Because there are more than two proportions to be compared, a Chi-Square test of association is appropriate for each randomization strategy. To perform the analysis, researchers would construct a two-way table with the six marking locations as categories of the first variable, migration success or failure as categories of the second variable, and cell counts that show the results for the 3600 butterflies. A Chi Square test of association of marking location and success of migration would be used to test the null hypothesis

Additional Notes

In this example only one treatment, labeling a location, is being applied. Since there are six different locations, there are six levels of this factor. We could apply a second treatment, for example, color of the label, with several levels. Suppose that the colors of the labels are yellow and blue. Then we would have 12 treatments from 6 levels of one factor (location) and 2 levels of a second factor (color).

See the discussion and examples of randomization in *Introduction to Statistics and Data Analysis* by Peck, Olsen and Devore, 2001 p. 42. and *Mind on Statistics* by Utts and Heckard, 2002, p. 63.

A Chi-Square test of association is a term that encompasses tests of significance for both tests of homogeneity and tests of independence. The test procedure is identical for both designs. In part A the significance test is a test for homogeneity. In part B the significance test is a test of independence. A thorough discussion of these ideas can be found in *Introduction to Statistics and Data Analysis,* Peck, Olsen, Devore, 2001, P. 599 – 622 and in *Mind on Statistics,* Utts and Heckard, 2002, p. 460 – 479.

1999 Free Response *Question 3*

Synopsis of Question

The problem stem described a study in which dentists in a dental clinic were trying to determine whether the number of new cavities differs for people who eat an apple each day and for people who eat less than one apple per week. It was clearly stated that two groups of clinic patients would be studied. One group would consist of 50 patients who report that they eat an apple each day; the other group would consist of 50 patients who report that they eat less than one apple per week. Dentists would examine patients and their records to determine the number of new cavities the patients had over the preceding two years and compare the numbers in the two groups.

Links to College Board Resources

Full text of this question is available at:

http://www.collegeboard.org/ap/statistics/frq99/a_q3.html

The Chief Faculty Consultant's notes on student performance are available at:

http://www.collegeboard.org/ap/statistics/frq99/student_perf3.html

The scoring guidelines for this question are available at:

http://www.collegeboard.org/ap/statistics/frq99/sg_a_q3.html

Discussion of Concepts

This question tests students' understanding of the difference between an experiment and an observational study, the concept of confounding in an observational study, and the issue that statistically significant results from an observational study cannot be attributed to cause and effect.

The question *observational study* versus *experiment* is relatively straightforward when this study is evaluated in regard to the textbook definitions for these terms. It is important that students realize that apple consumption is the explanatory variable in this study and that the patients for the two comparison groups were identified based on their apple consumption history. Students who read the problem stem carefully should see that in this study no treatments were imposed, no factors were manipulated, no patients were asked to do anything differently. Rather, the dentists simply ask about the frequency of eating apples and then observe all patients to determine the number of new cavities, which is the response variable.

To fully address the issue of confounding, students must be aware that in this study, like most other studies, the response variable is likely to be influenced by variables other than the explanatory variable. In *Mind on Statistics* by Jessica M. Utts and Robert F. Heckard (Duxbury, 2002, page 58), it is stated, "A confounding variable is a variable that both affects the response variable and also is related to the explanatory variable." According to *Introduction to Statistics and Data Analysis* by Roxy Peck, Chris Olsen, and Jay Devore (Duxbury, 2001, page 19), "A confounding variable is one that is related both to group membership and to the response variable of interest in the research study." In this example, the overall diet of the patients is likely to be a confounding variable. The overall diet is likely to affect the number of new cavities (the response variable) since a more healthy diet most likely includes less sugar, and sugar has been linked to increased cavities. Further, the overall dietary habits are likely to be related to the explanatory variable because people who eat an apple every day are likely to be making healthy snack or dessert choices and consequently eat fewer sweets than a person who seldom eats apples.

To help students better understand confounding, it might be helpful to consider a variable that is likely to influence the response variable but that would not be considered to be a confounding variable. One might argue convincingly that people who regularly visit a dentist are more likely to have fewer new cavities because they are more concerned and pay more attention to their dental health. Thus the variable of dental visits is one that is likely to affect the response variable. This variable, however, is probably not related to group membership. Since all the subjects are clinic patients, they all have been visiting a dentist. Some patients may have scheduled regular visits while others have not, but there is no reason to think that the regular visits relate to apple groups. So in this situation, it is unlikely that the variable of dental visits is confounding.

In light of possible confounding variables, researchers could not attribute a significant difference in means to eating an apple a day. Only when researchers conduct a well-designed *experiment* would a cause-and-effect conclusion be valid. In a well-designed experiment, random assignment of subjects to treatment groups assures that groups are similar in all respects *except* for the treatment. Therefore, any difference in outcomes can be attributed to the treatment (explanatory variable). In an observational study we cannot draw conclusions of cause-and-effect because there is a possibility that differences in outcomes are due to some variables other than the explanatory variable being studied.

Additional Notes

The study described in this problem provides a good context for a class discussion of samples of convenience and scope of inference. Note that the samples for this study consist only of patients who visit one particular dental clinic. Therefore the scope of inference would be restricted to the population of patients who have visited this dental clinic.

Additional Resources

Newspaper and magazine reports of recent statistical studies provide many opportunities for classroom discussions of the type expected by this problem. A sample student activity designed to assess understanding of these concepts related to current articles is provided as **Attachment 2** at the end of this document.

2000 Free-Response *Question 5*

Synopsis of Question

The problem stem described a situation where researchers wanted to compare the effects of a new drug to the effects of an existing drug for reducing cholesterol levels in patients. Students were to design a completely randomized experiment using volunteers with a history of high cholesterol levels. After the initial design, they were to create an improved design that incorporates blocking. The final part of the question asked if the experiment could be carried out in a double-blind manner.

Links to College Board Resources

Full text of this question is available at:

http://www.collegeboard.org/ap/statistics/frq00/index.html

The Chief Faculty Consultant's notes on student performance are available at:

http://www.collegeboard.org/ap/statistics/frq00/student_perf4.html

The scoring guidelines for this question are available at:

http://www.collegeboard.org/ap/statistics/frq00/index.html

Discussion of Concepts

This question tests the students' understanding of completely randomized, randomized block, and double-blind experiments. The explanatory variable is the drug and the response variable is cholesterol level.

In discussing the completely randomized design, it is important that students understand the need to create at least two treatment groups. One group receives the old drug, and one group receives the new drug. A third group could receive a placebo, but it is **not necessary** to have this group. In fact, once a drug exists that is known to work, a placebo should not be used for ethical reasons. Subjects should be randomly assigned to the treatment groups in order to create "equivalent" treatment groups with respect to factors other than drug type that might affect the response variable. To determine the effectiveness of the drug, there must be a comparison of the cholesterol levels of the groups at the end of the experiment.

In describing a design that incorporates blocking, the students are expected to recognize that there are factors besides the drug that could affect cholesterol levels. They are expected to design an experiment that uses one of these variables as a blocking factor. For example, if they believe men and women will react differently to the drug, then they could partition the subjects into two blocks based on gender. One block would contain all of the females in the experiment and the other block would contain all of the males. Within the block of females each subject would be randomly assigned to one of the treatment groups. Similarly, within the block of males each subject would be randomly assigned to one of the treatment groups. Blocking on gender controls for any variability in the response variable that is due to gender.

Another possible factor to use for blocking would be the amount of exercise performed by each subject. Since the problem states that exercise affects cholesterol levels in the body, it certainly would be reasonable to assume the amount of exercise for the subjects would affect the final levels of cholesterol. The person conducting the experiment could divide the subjects into blocks based on their level of exercise, for example low, moderate and high exercise levels. Once the blocks are determined, subjects within each block must be assigned to the treatment groups randomly.

It should be noted that students should present some justification for their choice of a blocking variable. They could say they chose to block on exercise because the problem indicates it is a factor. They might say they believe that men and women react differently to drugs so they blocked for gender. They could indicate that initial cholesterol levels might affect final cholesterol levels, so they are placing subjects with higher levels of cholesterol in one group and the remaining subjects in a second block.

The question of whether the experiment could be conducted as a double-blind study is relatively straightforward. A double blind experiment requires that the subjects are not aware of the treatment they are receiving, and the person administering the treatment or monitoring the results is not aware of the treatment. This certainly seems plausible for either design. Note that "blind" refers only to the treatment imposed, not to the blocking variable.

Additional Resources
An activity that uses simulations for the cholesterol problem was developed at the NCSSM Statistics Leadership Institute 2000 and can be found at:
http://phywww1.ncssm.edu/green/Math/Stat_inst01/PDFS/block.pdf

2001 Free-Response *Question 4*

Synopsis of Question

A study was to be designed for the purpose of comparing the productivity of two different types of dwarf fruit trees. The site for the experiment was a field bordered on one side by a forest. Students chose the better of two block designs and justified their choice. They were asked to explain the purpose of random assignment within the blocks. Each block was to contain two trees of each variety.

Links to College Board Resources

The full text of this question, the Chief Faculty Consultant's notes, and the scoring guidelines can be found as part of a file of the complete 2001 exam at:
http://www.collegeboard.org/ap/statistics/frq01/index.html

Discussion of Concepts

The objective of the question is to test students' understanding of the concept and purpose of a *block design* and the need for *randomization* within such a design. The *experimental unit* is the plot of land. The *explanatory variable* is the variety of fruit tree, while the *response variable* is the productivity of the trees planted in these plots.

From the information and picture given with the problem, students are supposed to understand that the shading schemes shown in the diagrams divide the plots of land into *blocks* and ***not*** into *varieties* of trees. According to *The Practice of Statistics* by Daniel Yates, David Moore and George McCabe (W. H. Freeman, 1999, p. 281), "A block is a group of experimental units or subjects that are similar in ways that are expected to affect the response to the treatments." Since the forest is expected to have an impact on the productivity of the fruit trees, an appropriate *block design* should ensure that each treatment group has comparable exposure to the forest. In the *Introduction to the Practice of Statistics* by David S. Moore and George McCabe (W. H. Freeman, 1993, p. 243), "Blocks are another form of *control*. They control the effects of some outside variables by bringing those variables into the experiment to form the blocks."

In order for plots in the same block to have similar exposure to the forest, it appears that blocking **scheme A** (where one block is next to the forest and one block is away from the forest) is the one that will create homogeneous groups of plots with respect to the forest. Blocking **scheme B** does not produce homogeneous groups because both blocks contain plots adjacent to and away from the forest. This scheme would allow for the possibility that all of one variety of tree would be planted next to the forest.

In addressing the need for randomization, students should consider whether there are other variables that may affect productivity. *Mind on Statistics* by Jessica M. Utts and Robert F. Heckard (Duxbury, 2002, p.66) states: "Students are sometimes confused by the reasons for blocking and for randomization. One method is used to control *known* sources of variability among the experimental units, and the other is used to control *unknown* sources of variability." In this situation, the *known* source of variability is the forest whereas the *unknown* sources of variability could be factors such as the fertility, moisture, or soil conditions of each plot. These conditions could affect the productivity of the trees. Consequently, in order to balance (or equalize) the effects of these *unknown* sources of variability, it is appropriate to assign the varieties of trees randomly to the plots within each block.

Additional Notes

Although the problem did not ask for methods of randomization, discussions with students could focus on this issue. One possible method: Begin the assignment process by selecting one of the blocks. In that block, select a plot and flip a coin to determine the variety of tree to be planted. In the same block, select a second plot and flip a coin to determine the variety of tree to be planted there. If the second tree selected is the same variety as the first, plant the remaining variety of trees in the remaining plots. If it is different, select a third plot; flip a coin to determine the variety for that plot. Since there is but one plot remaining and one variety of tree, plant the remaining tree in the remaining plot. Repeat this procedure for the other blocks.

Additional Resources

Two activities were developed at the Statistics Leadership Institute 2001. The first is titled *Can You See the Forest for the Trees* by Peter Flanagan-Hyde. The second is *Trees* by John Lieb and is contained in his TI 83 programs. Both can be found in the 2001 Statistics Leadership materials.

Additional Resources From the Statistics Leadership Institute

Participants in the *Statistics Leadership Institute* have produced other projects that are related to experimental design. Listed below is a synopsis of some of those projects. All projects developed in the summers of 2000 and 2001 can be accessed at: http://phywww1.ncssm.edu/green/math/ConfWork.html

1. Projects Using Paper Helicopters by Gloria Barrett and Floyd Bullard

There are three listings on the web site for these projects. The first, titled **Experimental Design Project Helicopters,** lists the various types of statistical inference for AP Statistics and explains how experiments with paper helicopters can be designed to answer a wide variety of questions. It was presented at NCTM in 2000 and can be found directly by going to: http://phywww1.ncssm.edu/green/Math/Stat_inst01/PDFS/expdesign.pdf

The second listing titled **Helicopter Theme and Variation** contains a template for the helicopters with instructions for their construction. It lists possible explanatory and response variables. Sample experimental designs prepared by the authors for the various inference procedures are included using. You can access this page directly by going to: http://phywww1.ncssm.edu/green/Math/Stat_inst01/PDFS/theme_var.pdf

The final listing titled **Sample Student Design** contains eight designs submitted by students. They are presented for analysis at: http://phywww1.ncssm.edu/green/Math/Stat_inst01/PDFS/stusamp.pdf

2. Helicopter Activities to Compare Two Sample and Paired Designs, by Laura Hanna, Janet Hassan, and Beverly Johnson, NCSSM Statistics Leadership Institute 2000

This activity uses paper helicopters to perform completely randomized two-sample experiments and paired (randomized block) experiments. Classroom ready data collection sheets, instructions, and related questions are provided.

An extensive teacher's solution guide provides answers to all procedures. In addition, computer printouts of the results are shown using JMP-IN. More teacher notes, commentary, and suggestions for other studies are also provided. The final section has copies of templates for the activities.
A direct link to this document is:
http://phywww1.ncssm.edu/green/Math/Stat_inst01/PDFS/helitests.pdf

3. An Exercise in Sampling: Rolling Down the River by Carolyn Doetsch, Peter Flanagan-Hyde, Mary Harrison, Josh Tabor, and Chuck Tiberio, NCSSM 2000

Part one asks students to use different methods for selecting a sample of ten plots from a field represented on a 10 by 10 grid. The methods to be used are: convenience sample, simple random sample, stratified sample (vertical), and stratified sample (horizontal). A grid with the yield per plot is given. Students are to calculate the mean yield per plot and estimate the total yield of the field. Related questions are included.

Part two of this exercise asks students to repeat the analysis using a new grid for the yield of each plot. Teachers' notes, other observations, and a solution key complete the packet.

A direct link to this document is:
http://phywww1.ncssm.edu/green/Math/Stat_inst01/PDFS/river.pdf

4. More Than Your Heart Desires…An Exploration in Blocking by Carolyn Doetsch, Peter Flanagan-Hyde, Mary Harrison, Josh Tabor, and Chuck Tiberio, NCSSM 2000.

This problem is an extension for the 2000 AP Statistics Examination Free Response "cholesterol problem". It was developed at the NCSSM Statistics Leadership Institute, 2000. It contains a data set that models the problem, classroom ready data collection sheets, instructions, and related questions that students can use to simulate the "cholesterol" problem. The project may be accessed at: http://phywww1.ncssm.edu/green/Math/Stat_inst01/PDFS/block.pdf

5. Can You See the Forest for the Trees by Peter Flanagan-Hyde.

This problem provides an extension for the 2001 AP Statistics Examination Free Response "fruit tree" problem. Using this activity, students can simulate data sets that model a completely randomized design and two different block designs for this problem setting. Classroom ready data collection sheets are provided. It was developed at the NCSSM Statistics Leadership Institute 2001 and can be found with those materials.

6. Trees by John Lieb.

This problem provides an extension for the 2001 AP Statistics Examination Free Response "fruit tree" problem. Using this activity, students can simulate a completely randomized design and two different block designs on their TI 83. It was developed at the NCSSM Statistics Leadership Institute 2001 and can be found with those materials.

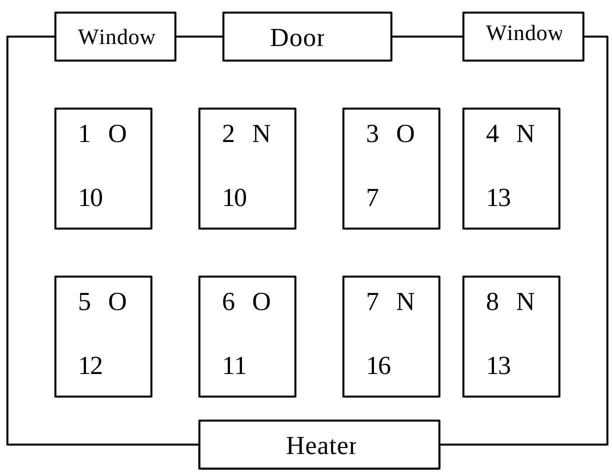
Attachment 1

Fishtank Problem Activity

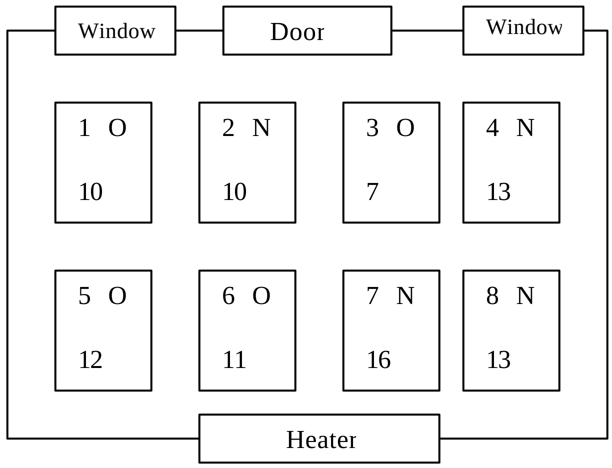
This problem is based on the "Fishtank" problem that appeared on the 1997 AP Statistics exam. This activity was suggested by Dan Teague at the North Carolina School of Science and Mathematics Statistics Leadership Institute 2001.

A new type of fish food has become available for salmon raised on fish farms. Your task is to design an experiment to compare the weight gain over a six-month period of salmon raised on the new and old types of food. The salmon you will use for the experiment have been randomly placed into eight large tanks in a room with a considerable temperature gradient. In the diagrams below, O represents a tank in which the salmon are fed the old type of food and N represents a tank in which the salmon are fed the new type of food. The weight gain is given for the fish in each tank. Note that each tank contains a single fish.

A. The first design is a completely randomized design. Is there evidence of a significant increase in weight gain for fish fed the new type of food?



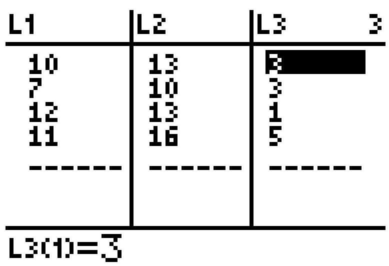
B. The second design uses blocks where tanks are grouped to address temperature gradient and the possible effects of the windows and doors. Does this design appear to be better than the completely randomized design for detecting a significant increase in weight gain for the fish fed the new type of food?



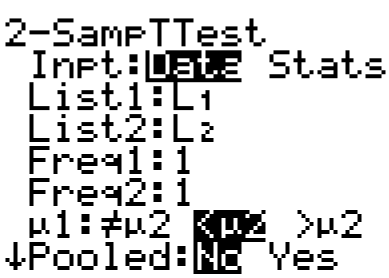
Teacher Notes

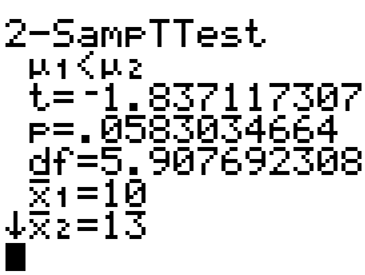
The weight gains are obviously "Made-up" data and not the results of an experiment. In the first case where the design is a completely randomized design, a two-sample t-test can be executed to test for significance. In the second case, the design is a randomized block where the blocks consist of pairs (1, 4), (2, 3), (5, 8), (6, 7). Notice that tanks within these blocks are homogeneous with respect to the temperature, windows and doors. Treatments (food type) are assigned randomly within each block. These data are analyzed using a t-test on the paired differences.

TI-83 Plus calculator screen images for each of the analyses are provided below. L1 contains the weight gains for the salmon fed the "old" food, L2 contains the weight gains for the salmon fed the "new food," and L3 contains the difference in weight gain for each block.



For the *completely randomized design*, the only factor considered is the effect of the food. We are assuming that the weight gains are normally distributed for each population. The screens for the tests and the results follow. Notice that in this example, the results are not significant.





The second design uses blocks where tanks are grouped by temperature gradient and possible effects of the windows and doors. Data are analyzed using a t-test on the paired differences stored in L3. Notice that in this example, the results are significant.

```
T-Test
 Inpt:Data Stats
 μ0:0
 List:L3
 Freq:1
 μ:≠μ0 <μ0 >μ0
 Calculate Draw
```

```
T-Test
 μ>0
 t=3.674234614
 p=.0174484923
 x̄=3
 Sx=1.632993162
 n=4
```

Attachment 2

ANALYSIS OF STATISTICAL STUDIES

Group Members:____

Article Title:____

1. Does this article report an experiment or an observational study?

2. What was the response variable?

3. What was the explanatory variable?

4. What was the population?

5. Describe the sample. Be sure to indicate the sample size.

6. If this was an observational study, is there a confounding factor lurking in the background? If so, describe or explain that factor.

7. If this was an experiment,

a) How were experimental units assigned to treatment groups?

b) Was there a placebo group?_______ If not, should there have been one or is there a good reason not to have one?

c) Was the experiment run blind, double blind, or neither? Explain.

d) What were the factors used in the experiment?

e) Identify the levels of each factor.

8. What was the conclusion of this study?

9. Do you have any concerns associated with this study that you have not addressed in your answers to the questions above? If so, what are they?

Textbook Reference List

Cobb, George W., (1998), *Design and Analysis of Experiments*, New York, Springer-Verlag.

Freedman, David, Pisani, Robert, and Purves, Roger (1998), *Statistics*, New York, W.W. Norton & Company.

Moore, David S., and McCabe, George P. (1993), *Introduction to the Practice of Statistics*, New York, W.H. Freeman.

Peck, Roxy, Olsen, Chris, and Devore, Jay (2001), *Statistics and Data Analysis*, California, Duxbury.

Utts, Jessica M., and Heckard, Robert F. (2002), *Mind on Statistics*, California, Duxbury.

Yates, Daniel S., Moore, David S., and McCabe, George P. (1999), *The Practice of Statistics*, New York, W.H. Freeman.