STATISTICS 402 - Assignment 4
Solution

1. For each of the following descriptions indicate what the response is, what the conditions are (i.e. factors of interest) and what the experimental material is. Then discuss whether or not the experiment adheres to the three fundamental principles of a designed experiment: control of outside variables, randomization, and replication within the experiment. If the experiment adheres to a principle describe how. If the experiment does not adhere to a principle indicate how you would change the experiment to make it better. Be specific and be sure to comment on all three principles.

   a) An aluminum smelting operation makes its own carbon anodes for use in their aluminum smelting pots. The density of the anode is an important quality characteristic because it affects the usable life of the anode. An experiment is conducted to see the effect of bake temperature on anode density. Twenty anodes are made using the same raw materials, methods and people. Five anodes are assigned at random to each of four temperatures, 500, 525, 550 and 575 ^{o}C. A temperature is picked at random and the five anodes are baked in the oven at that temperature. One of the remaining temperatures is picked at random and the five anodes are baked in the oven at that temperature. This random selection of a temperature and baking 5 anodes continues until all temperatures have been used once. The density of each anode is then measured. The order in which the anodes have their density measured is completely random.

   The response is the density of the baked anode.
   The conditions are the four temperatures for the baking oven.
   The experimental material consists of the 20 anodes.

- **Control of outside variables: This principle is adhered to. The anodes are made using the same raw materials, same methods and same people, so control is exercised over these outside variables. Additionally, the same oven is used to bake all the anodes.**
- **Randomization: This principle is adhered to partially. It is adhered to in the measurement process where the order in which the anodes have their density measured is completely random order. The order of the temperatures is also selected at random.**
- **Replication: This principle is not adhered to. Although there are five anodes for each temperature, they are all baked at the same time. There is not true replication of the temperature setting.**

   To incorporate replication, the baking order of the 20 anodes should be completely randomized. This may require baking only one anode at a time at a randomly selected temperature. To do this, put 20 poker chips in a bag (5 labeled 500, 5 labeled 525, 5 labeled 550 and 5 labeled 575). Mix chips, draw out one chip and bake an anode at that temperature. Repeat this process until all 20 anodes are baked.

b) A chemist wants to compare a new, and simpler, method for determining the concentration of a solution with the standard method. She prepares a batch of solution, divides it into 40 specimens, and then selects 20 at random. She asks her technician to analyze these 20 specimens using the new method and the remaining 20 using the standard method. The technician finishes analyzing the 20 specimens using the new method in the morning. He takes a break for lunch and does the remaining 20 specimens using the standard method in the afternoon.

The response is the concentration of the solution.
The conditions are the two methods (new and standard).
The experimental material consists of the 40 specimens of the batch of solution.

- **Control of outside variables: This is partially adhered to. There is one batch of solution. There is one technician doing all of the analyses. However, the technician does the new method in the morning and the standard method in the afternoon. The time the concentration is determined is confounded with the method.**
- **Randomization: This is not adhered to. Doing all the new method before lunch and all the standard method after lunch can introduce unplanned systematic variation. The technician may get hungry before lunch and not be as focused. Alternatively, the technician may be sleepy after lunch and be more careless. The solution may also be affected by time so that the specimens after lunch may be different from those before lunch.**
- **Replication: This is adhered to in that there are 20 observations for each method. Because there is only one batch of solution, we are limited in our generalization to comments on how the methods compare for that one batch.**

To improve the experiment, randomize the order of the analysis of the 40 specimens. Put 40 chips in a bag (20 with "new" on them and 20 with "standard" on them). Mix the chips, draw a chip, without replacement, and perform an analysis with the method specified on the chip. Repeat this process until all specimens are analyzed. With only one solution, the result of the experiment will be valid for that one solution. For greater generalization, include several batches of solution.

c) A research psychologist wishes to investigate the difference in maze test times for mice trained using different types of reinforcement; no reinforcement, positive reinforcement (food given for a correct choice), negative reinforcement (mild electric shock given for an incorrect choice). Thirty mice are available for the experiment. For each mouse a fair 6-sided die is rolled. If the roll is a 1 or 4 the mouse is assigned to group 1 (no reinforcement). If the roll is a 2 or 5 the mouse is assigned to group 2 (positive reinforcement). If the roll is a 3 or 6 the mouse is assigned to group 3 (negative reinforcement). After rolling the die 30 times there are 7 mice in group 1, 12 mice in group 2 and 11 mice in group 3. The design of the maze used to train the mice is the same for all mice. After training, each mouse is run in a new maze and the time to complete the new maze is recorded. The design of the new maze is the same for all mice.

The response is the time to complete the new maze.
The conditions are the three types of reinforcement.
The experimental material consists of the 30 mice.

- **Control of outside variables: This is adhered to partially. A maze of the same design is used to train all mice. A new maze, the same design for all mice, is used to test all mice.**
- **Randomization: This is adhered to in the assignment of mice to treatment groups. The use of the die, with no stopping rule, provides complete randomization. Before randomizing there is a small chance that you will not get replication for one of the groups. If this happened then you would have to run the experiment without proper replication. In a sense, the experimenter lucked out by getting several mice in each treatment group. In general, using a die, in a way similar to what was done here is not advisable. A better way to randomize would be to put 10 red chips for group 1, 10 blue chips for group 2 and 10 white chips for group 3. Mixing and drawing the chips, one at a time without replacement, for each of the 30 mice is a better randomization method.**
- **Replication: This is adhered to. Although there are different numbers of mice in each group (imbalance), there are several mice in each group.**

  The experiment could be improved by having more control. For example, all of the mice should be the same breed, age and gender. Outside of the training, the mice should be treated the same i.e. housing, food, exercise, etc.

2. Below are two scenarios for an experiment involving chocolate chip cookies. Different recipes for the cookies are used. Trained tasters evaluate the cookies on moistness, texture, flavor, greasiness and appearance. The evaluations are combined to give an overall appeal score for the cookie with higher values indicating greater appeal.
   - Scenario 1: One batch of cookie dough is made with vegetable margarine, one batch with vegetable oil, one batch with butter and one batch with vegetable shortening (Crisco). Twenty cookies are baked from each batch of dough.

   - Scenario 2: Five batches of cookie dough are made with vegetable margarine, five batches with vegetable oil, five batches with butter and five batches with vegetable shortening (Crisco). Four cookies are baked from each batch of dough.

   a) What is the response? What are the conditions (i.e. factor of interest)? What is the experimental material?

      Response: Overall appeal score.
      Conditions: Type of shortening.
      Experimental material: Batches of cookie dough.

   b) What is the planned systematic variation in the experiment?

      The planned systematic variation is the variation in the overall appeal score due to the differences in shortening.

c) For each of the scenarios describe what the chance variation is in the experiment and the source of this variation. Be specific.

For both scenarios, chance variation will come from variation in temperature in the oven, placement on the cookie sheet, differences among trained testers and quality of the ingredients used.

Scenario 1:
Chance variation comes from differences in appeal scores for cookies from the same batch of dough. This variation could be due to not thoroughly mixing the batch of dough so that the shortening is not evenly distributed throughout the batch. Cookie to cookie variation.

Scenario 2:
Chance variation comes from differences in appeal scores for cookies from the same batch of dough. This variation could be due to not thoroughly mixing the batch of dough so that the shortening is not evenly distributed throughout the batch. Cookie to cookie variation. Chance variation also comes from differences between batches made with the same type of shortening. This variation could be due to differences in the amount of shortening in each batch. Batch to batch variation.

d) Suppose cookies made with butter are found to have a significantly higher mean appeal score than those made with vegetable products. For each of the scenarios discuss what sort of generalization can be made?

Scenario 1:
If there is any dough left over from the batches used in this experiment, additional cookies from the batch made with butter would have a higher average appeal score than cookies made from the remaining dough in the other batches.

Scenario 2:
Cookies made using the butter recipe will have a higher average appeal score than cookies made using the recipes for the other types of shortening.