EXPERIMENTAL DESIGN WORKSHEET **MTH-1210**

1. Principles of Experimental Design

1.1. **Principles of Experimental Design.** The objective of experimental design is to conclude that differences in the *response variable* of an experiment are results of differences in the *treatments* being considered and can not be reasonably attributed to random error. Three principles are employed to allow researchers to make these conclusions:

- **Control**: Two or more treatments should be compared.
- **Randomization**: The experimental units should be randomly divided into groups in order to avoid selection bias.
- **Replication**: The more experimental units that are sampled according to each treatment, the more reliable the conclusions of the experimental design.

1.2. **Definitions.**

- **Experimental Unit/ Subject** - The individuals or items on which the experiments are performed; if the experimental units are people, they are called *subjects*.
- **Response Variable** - The outcome of the experiment that is being measured. This should be a measurement of some quality of the experimental unit/ subject.
- **Factor** - A variable whose effect on the response variable is of interest.
- **Level** - The possible values of a given factor.
- **Treatment** - Each experimental condition; that is, each possible combination of factor and level. For one-factor experiments, the treatments are simply all the levels of the single factor.

1.3. **Blocking.** Blocking is an experimental design technique used to eliminate known bias. For example, if one was testing the durability of motorcycle tires, they may want to use the same three weights of motorcycles when testing each treatment in the design; this way, we would eliminate the possibility of one treatment (e.g. type of tire) being tested only by lightweight motorcycles while another treatment is tested only by heavier motorcycles, hence biasing the results.

If an experimenter is *not* using a blocking technique then a *completely randomized design* is being used. In a **completely randomized design**, all experimental units are assigned equally among all treatments.

Alternatively, in a **randomized block design**, the experimental units are assigned randomly among all the treatments separately within each block. That is, each block has it own set of uniquely-defined (according to the block definitions) experimental units.

2. Practice Problems

2.1. **Completely Randomized Designs Practice Problems.**

2.1.1. *Practice Problem.* In a classic study (F. Yates, 1978) the effect on oat yield was compared for three different varieties of oats and four different concentrations of manure (0, .2, .4 and .6 cwt per acre). Identify the experimental units, response variable, factor(s), levels of each factor and treatments in this example *in terms of the problem.*

2.1.2. *Practice Problem.* A groundwater specialist is interested in levels of sulfur in three adjacent canyons. The specialist has the resources to drill wells in each canyon and chemically analyze 20 samples from each well for sulfur content. She is interested in detecting differences in sulfur concentration between the canyons in question. Identify the experimental units, response variable, factor(s), levels of each factor and treatments in this example *in terms of the problem.*

2.2. **Randomized Block Designs Practice Problems.**

2.2.1. *Practice Problem.* A chemist wishes to test the effect of four chemical agents on the tensile strength of a particular type of cloth, measured in grams per denier (gpd). The raw cloth is delivered in bolts, and one expects significant tensile strength variability between bolts. What type of experimental design should be used? If 24 samples of each treatment will be taken, but each bolt only supplies 12 samples total, then how should the experiment be designed in order to eliminate the effect of bolt variability?

3. Worksheet Problems

3.1. **Problem.** A brick manufacturer is interested in the effect different firing temperatures (100°, 150°, and 200° Celsius) have on the density of the brick that is produced. Identify the experimental units, response variable, factor(s), levels of each factor and treatments in this example.

3.2. **Problem.** Suppose the brick manufacturer in the previous problem has exactly two brick ovens at the factory, and uses both of them during production. Also suppose that there is enough time and resources to test 30 bricks total. Design a *randomized block design* that eliminates possible biases in the differences of the two ovens.

3.3. **Problem.** A wine producer is interested in the effect of two oak types and two fermentation temperatures (78° and 83° Fahrenheit) on the quality of wine, as decided by the average overall ranking by a panel of experts. Identify the experimental units, response variable, factor(s), levels of each factor and treatments in this example.

3.4. **Problem.** Suppose that the wine producer from the previous problem is interested in statistically comparing the effects of the treatments we identified in the previous problem. Design a completely randomized design for this experiment. Make sure each treatment is sampled at least 5 times.

3.5. **Problem.** Suppose that the vineyard in the previous problem was a relatively small vineyard bisected by a creek. The wine producer is concerned with the effect of bias in the previous experiment due to the location (North or South) of the grape plants with respect to the creek. Design a randomized block design for this experiment that addresses bias due to location of plant with respect to the creek. Make sure each treatment is sampled at least 5 times.

Appendix A. Solutions to Practice Problems

A.1. **Solution to Practice Problem 2.1.1.**

- The *experimental units* are the oat plants.
- The *response variable* is yield.
- There are two *factors*, variety of oat and concentration of manure.
- There are three *levels* of oat variety, one for each variety being tested here. There are four *levels* of manure concentration, 0, .2, .4 and .6 cwt per acre.
- There are 12 *treatments* total, one for each combination of variety and manure concentration.

A.2. **Solution to Practice Problem 2.1.2.**

- The *experimental units* are the groundwater samples.
- The *response variable* is sulfur content.
- There is one *factor*, the location of canyon.
- There are three *levels* of canyon location because we are testing three particular canyons.
- There are three *treatments* total since there is exactly one factor and three levels of that factor.

A.3. **Solution to Practice Problem 2.2.1.**

- The *experimental units* are pieces of cloth.
- The *response variable* is tensile strength (gpd).
- There is one *factor*, type of chemical agent.
- There are four *levels* of the factor because there are four chemical agents being tested.
- There are four *treatments* total since there is exactly one factor and four levels of that factor.
- In order to eliminate potential bias due to bolt source of the samples, the experimental design should be a randomized block design. Each bolt of paper should represent a block and be divided roughly equally among the treatments. Since only 12 samples can be taken from each bolt, three samples from each bolt will be exposed to each of four chemical agents. Since 24 samples of each treatment are needed, we will need to use 8 bolts of paper; therefore, we will use 8 blocks total.