Chapter 1

Concepts and Basis of Experimental Design

Concepts and Basis of Experimental Design

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Abstract

The concepts and basic terms underlying experimental designs are not well understood by students and some researchers. For experimental designs to be understood, the various terms used and applied in designing an experiment must be well explained. Some of the terms used and applied in the field of experimental designs are quite wrongly used and applied by students and many others involved in research. This paper defines and explains the terms comprehensively.

Keywords

Experimental Design, Treatment, Bias, Randomization, Experiment, Variance, Variable

1.1 Introduction

There is variability in all living and non-living things that exist in nature. Even though things may be categorized or classified into a particular group, there still could exist variability between things placed in the same group. Variations exist more in living things than in non-living things because of their characteristics – growth, reproduction, excretion, irritability, movement, respiration. The variability in living organisms may be linked to special functions they play. Some plants have narrower leaves than others; others have their leaves reduced to spine as a way of conserving water loss through respiration and transpiration. Some human beings are ambidextrous, thus they are able to do so many things at a goal. It is very important as a matter of fact when researching on things to be able to ascertain and quantify the variability between them. In order to do this, there is a need for one to design experiments to prove statistically how variables differ or relate to each other.

Oftentimes people complain of the mathematical principles on which the concept rests as it is tedious working such calculations manually. In the advent of computers, computations have been made quite easy but the underlying principles need to be understood before using computers to do the various calculations. It will also explain and define the terms used in the design of experiments as well as the types of design and when they are supposed to be used in experiment.

1.2 Terms Used in Experimental Designs

There are so many terms one to know and understand in the designing of experiment. When these terms are not properly understood and used by the

designer, it would lead to confusion and wrong results being churned out at the end. Some of the terms are explained below.

1.3 Experimental Design

It refers to the allocation of treatments to experimental units or materials or plots. Normally when an experiment is to be mounted, it must first be designed. Thus experimental design encapsulates how an experiment must be conducted, and how data collected is to be collected, analysed and interpreted. It therefore suggests that every experiment (not survey) must have its unique and appropriate design.

1.4 Experiment

It is an investigation where an investigator imposes treatment(s) on experimental units to ascertain the effects on the unit by the measurement of response variables on the unit due to the imposition.

When one wants to conduct an experiment, the individual considers what to perform the experiment on (experiment unit or material) and what to use on the experiment unit to be able to study their effects on the unit (treatment) and the measurements to take from the units (response variable) in order to arrive at conclusion. However, a researcher can have a test and a controlled experiment.

1.5 Test Experiment

In a test experiment, all conditions or treatment are made available except the treatment the researcher is interested in investigating for effects on the experimental material. For instance, if the researcher wants to know the effects

of nitrogen on a plant growth, he / she provides all the conditions for plant growth with the exception of nitrogen. When all other need conditions all provided, whatever effects or defects that are observed are considered to be due to the condition lacked in the experiment.

1.6 Control Experiment

It is an experiment in which all treatments or conditions are necessary for the experimental material to allow the needed response variables to be observed and measured. This is the converse of the test experiment. The researcher would therefore compare the results from a test and a control experiment to do interpretation for a conclusion to be made.

1.7 Observatory Study

It is also an investigation in which no treatment is imposed on an experimental unit by the investigator but he or she observes and measures response variables on the unit.

1.8 Treatments

It is the set of conditions or circumstances created for an experiment or investigation. For instance an investigator might want to study the effect of acids on a particular experimental unit or material. The treatment one can then impose on the experimental unit to create and acid condition could be the introduction of an acid. Hence the acid becomes the treatment in this case.

1.9 Factor

It is an explanatory variable to be studied in an experiment and can be set at different values.

Once the treatment has been selected as acid, the experimenter might be interested in looking at more than one form or type of an acid. Each form or type of an acid thus becomes a factor in the experiment.

1.10 Level

The level of a factor refers to the different values of factors under consideration or to be studied. For example in the case of a treatment (acid condition), factors such as sulphuric acid, carbonic acid, hydrogen sulphide can all be considered as factors because they are all different kinds of acids. Now, the concentrations or the quantities of these acids used in creating the acidic conditions referred to as the levels of the factors

1.11 Replication

It refers to the number of times a complete set of treatment is repeated in an experiment. When a researcher applies the same treatment to the same experimental unit or materials, provided the conditions are the same, the response variables would yield the same measurement (the results should be the same). To ensure consistency in results, a researcher repeats the same treatments over the experimental units in order to minimize errors and biases which are likely to be overlooked when repetition or cross checking is not done.

1.12 Experimental Unit

It is physical entity or subject on which the treatment is applied independent of other units. In other words, it is what generates the response variable that the investigator needs to measure and observe to address the objective of the experiment. It should be noted that an experiment can have homogeneous or heterogeneous experimental units and thus might give different response variables. It is therefore important for the research to know if his or her units are homogeneous or not in order to apply the appropriate design.

1.13 A Plot

It is an example of experimental units - a smallest unit of land that a treatment is applied to. The conditions or compositions of a piece of land differ in chemically, physically and biologically. If an experiment needs to be conducted on a piece of land, these chemical, physical and biological are likely to affect the results. Thus a plot is just a small piece of land, where the variations in its chemical, physical and biological properties are expected to lesser.

1.14 A Block

It is a large area or experimental unit consisting of several identical units on which all or most of the treatments under consideration are applied. Thus plots can be blocked – can be classified into blocks in an experiment. This allows the experimenter to compare variations in all the treatments when considering heterogeneous experimental units.

1.15 Response Variable

A characteristic of an experimental unit observed or measured after a treatment has been applied to it. In other words, it is the reaction observable or measurable reactions generated by experimental units as a result of application or imposition of a treatment to/on it. These observations and measures are what the investigator analyzes to address the objectives of the experiment.

1.16 Explanatory Variable

It is the characteristics of a treatment (factor) that induces the experimental unit to generate a response variable.

1.17 Experimental Error

It is a measure of the differences between experimental units on which the same treatment is applied. It seeks to establish the variation or variances in the experimental units. These variations may stem from the units, the lack of uniformity in the way the investigator applied the treatment, uncontrolled external influences and others that cannot be explained (natural). For example, if the same treatment (seed of pepper) is applied on an experimental units (plots).

1.18 Randomization

It is the act of allocating treatments to plots in an experimental design such that each has equal chance of receiving each treatment – plots or experimental units are not favoured or discriminated against. Randomization reduces the incidence of biases in allocation of treatment. An experimenter can decide to

treat a particular unit differently due to personal beliefs or ideals thereby introducing errors. However, when treatments are randomized, this can never happen. Randomization can be done by using random numbers generated using the computer or random number tables. To give different ration of feed (treatments) to rats (experimental units), the quantity feeds can be written on a paper, folded, placed in a cup, mixed up, then picked randomly and them applied to the experimental units.

1.19 Single-Factor Experiment

It is an experiment in which the investigator varies only one factor while all the others are kept constant. For an experiment in which the treatment is an acid, the factors can be hydrochloric acid and sulphuric acid. The experimenter can choose to vary the concentration of one of the factors while maintaining the other. When this happens, the experiment becomes a single-factor experiment.

1.20 Multi–Factorial Experiment

It is an experiment in which all the factors involved in the experiment are varied unlike the single-factor experiment.

1.21 Full Factorial Treatment Design

In a full factorial treatment design, the treatments involve all possible combinations of the levels of the factors of interest.

1.22 Observational Unit

An observational unit is a unit on which the response variable is observed and measured. This unit can either be the same as the experimental unit in some cases and in other cases not. For instance, if seeds are sown on different types of soil to ascertain the yields of plants in those soils, the soil is the experimental units but the fruits on the plant become observation units.

1.23 Conducting an Experiment

To conduct an experiment, one needs to consider the following:

- *Identify, define and state the problem*

  One cannot investigate a problem without identifying it. The first and foremost thing to do is to identify and define the problem such that all could understand it as a problem that needs to be tackled and solved. The problem statement should be precise and concise. It should not be ambiguous.

- *State the objectives and develop a hypothesis of the study*

  The objectives of conducting the experiment must be clearly stated. They are basically the reasons for conducting the experiment. The problem can be woven to develop a hypothesis – a statement which is neither considered as true or false but needs to be investigated and proven to otherwise. It is therefore the data collected from an experiment carried out that can provide evidence for or against the hypothesis.

- *Designing and conducting the experiment*

Having identified, defined and stated the problem, the research needs to design appropriate experiment that would help him or her conduct relevant data to prove the hypothesis. The designing of the experiment therefore plays a crucial role in proving the hypothesis and hence achieving the stated objectives of the experiment. Research therefore needs to be well baked in experimental designs to be able to design good experiments.

- *Collecting data*

The execution of the experiment allows the researcher to collect data on the response variables from experimental units induced by explanatory variables from factors of the treatments being considered in the experiment or to observe and measure the response variables in the case of observatory studies.

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