MODERN LIBRARY & INFORMATION SCIENCE

for Information Professionals in Africa

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Introduction

Research is a very vital aspect of educational development. A significant feature in educational study is the design of research. In experimental studies, design is the pivot on which the study revolves. This chapter, therefore, gives an insight into the concept and types of design of experiments, also called experimental design. It is hoped and believed that the content of this heading, which nevertheless is not exhaustic, will serve as guide to researchers who desire to toe the path of experiment in their research endeavour.

Concepts

A design is a conceptual framework of a project. The term *design of experiment* refers, therefore, to the conceptual plan within which experiment is conducted. It is the framework for the conduct of the experiment. Designs of experiment differ in various ways:

(i) in number of independent variables that are manipulated because while some have only one independent variable, others have two or more;
(ii) in the method of assigning subjects to different treatments;
(iii) in how often dependent variable measure are made and whether all subjects receive all treatments or not.

Design of experiment functions in

(a) establishing the conditions for the comparison needed to test hypothesis of experiment.
(b) enabling the researcher to make meaningful interpretation of results of study through statistical analysis of data.

A researcher must therefore consider these functions before selecting a research design. Other criteria that must be considered in selecting a design is that the design must

(i) be appropriate for testing the particular hypothesis of the study;

(ii) provide adequate control so that the effects of the independent variable can be evaluated unambiguously.

An experiment is a scientific investigation in which the researcher manipulates one or more independent variables; controls any other relevant variables, and observes the effect of the manipulations on the dependent variable(s). In an experiment, an experimenter deliberately and systematically introduces changes and then observes the consequences of those changes. In its simplest form, an experiment has three characteristics:

1. an independent variable is manipulated;
2. all other variables that might affect the dependent variable are held constant;
3. the effect of the manipulation of the independent variable on the dependent variable is observed.

Thus, in an experiment, the two variables of major interest are the independent variable and the dependent variable. The independent variable is manipulated (changed) by the experimenter. The variable on which the effects of the changes are observed is called the *dependent variable,* which is observed but not manipulated by the experimenter. The dependent variable is so named because its value is hypothesized to depend on, and vary with, the value of the independent variable. For example, to examine the effect of different teaching methods on achievement in reading, an investigator would manipulate method (the independent variable) by using different teaching methods in order to ascertain their effect on reading achievement (the dependent variable).

An experiment must therefore involve experimental or treatment group(s) and control group(s). The treatment or experimental group(s) is (are) the group(s) to which the treatment is (are) administered. The treatment is the variable being manipulated and whose effect is under investigation. It can also be called *independent variable, experimental variable* or *treatment variable*. The effect of treatment variable is also, called the *dependent variable* or *criterion variable*. Another group of variable is experimental research is extraneous variables. An extraneous variable is a variable that is not related to the purpose of the research but has the ability to exert influence over the dependent variable. They have to be checked or controlled to eliminate any *confounding* effect they may exert on the experimental treatment. When confounding occurs, a 'mixing' of variables extraneous to the research problem with the independent variable occurs in such a way that their effects cannot be separated. It will be difficult to determine whether the relation found is between the independent variable and the dependent variable of the study or between the extraneous variables and the dependent variable or both of the two. To control extraneous variable effects, assignment of subjects to groups by randomization will be adopted to ensure similarity in characteristics.

Characteristics of Experimental Research design

There are three essential ingredients with which an investigator is actively involved in conducting an experiment.

1. Control
2. Manipulation
3. Observation

1. *Control*

A very essential feature of experimental design is the use of control. Control indicates the researcher's actions designed to eliminate the influence of undesired but significant variables as well as eliminate the differential effects of undesired but significant variables upon the different groups of subjects participating in an experimental study. Uzoagulu (1998) stressed that "the great rule is to vary only one circumstance at a time, and to maintain all other circumstances rigidly unchanged". Control of variables is the essence of the experimental method where researcher attributes the result to experimental treatment. To control the variables, the researcher holds constant all influences except the one under investigation. Without control, it is impossible to evaluate unambiguously the effects of an independent variable or to make inferences about causality. The purpose of control in an experiment, therefore, is to arrange a situation in which the effects of variables can be investigated.

Two assumptions underlying control in an experiment as developed by Mill (1873) and quoted by Ary et al (2002) are:

(i) that if two situations are equal in every respect except for a variable that is manipulated or added to or deleted from one of the two or more situations, any difference appearing (as measured through test) between the two or more situations can be attributed to that variable that was manipulated or added or deleted. Mill (1873) called this statement the *law of the single independent variable.*

(ii) that if two situations are not equal, but it can be demonstrated that none of the variables except the independent variable is significant in producing the phenomenon under investigation, or if significant variables other than the independent variable are made equal, then any difference occurring between the two situations after introducing a new variable (independent variable) to one of the systems can be attributed to the new variable. This, he called the *law of the single significant variable.* Educational research is concerned with human beings, and therefore, many variables are always present which act in combination to produce observed outcome. Any attempt to reduce the educational problems to the operation of a single variable would be unrealistic. It is appropriate to apply the law of the single significant independent variable, for instance, in a study of different effects of two methods of teaching English grammar. The researcher would have two groups of children who are identical in every respect except in the way in which they are taught English grammar. Other variables likely to be unrelated to English grammar are ignored such as height, shoe size or colour of hair. Procedures which permit comparison of groups on the basis of significant variables are very important in educational research.

Levels of Control

Ali (2006) identified the following three levels of control:

(a) ensuring that all the subjects, prior to the commencement of an experimental study are homogenous or equal or the same in characteristic e.g. if the achievement level of students in a Mathematics class are not the same, then the class is not homogenous.
(b) identification of the attributes of the independent and dependent variables and also subjects compliance with the manipulation and systematic observation of any changes arising from treatment condition.
(c) ensuring that extraneous variables such as those enhancing or mitigating events or threats to the study are removed or minimized.

2. ***Manipulation***

The manipulation of the independent variable is a deliberate operation by the experimenter in which he administers treatment to some participants and withholds it from others. It involves setting up different treatment groups or conditions and these different treatment groups or conditions administered to the subjects are the levels of the independent variable. Perhaps, the most common treatment manipulation is the instructional manipulation, i.e., manipulating the variable by giving written or oral instruction. There is also environmental manipulation which involves changing the participants' surroundings, e.g., adding or removing comfort. In setting up different groups or conditions, concerns about standardization errors, research bias, participant bias, validity of operational definitions being used are taken into consideration. In manipulating variables, a set of concerns that confront the researcher bothers on how much of the treatment should be administered and who gets what amount.

Manipulation may involve independent variables with predetermined values that differ in levels, for example, 'very thirsty', 'moderately thirsty' and 'slightly thirsty'. Here, the level of thirst is manipulated. A researcher may manipulate more than one independent variable in a single study.

3. *Observation*

After applying experimental treatment, a researcher observes to determine whether the hypothesized change has occurred. Proper and accurate observation characteristic of an experimental design study partly concerns the researcher's carefulness in determining exactly those attributes or outcomes in a study which have to be measured or recorded. In education, it involves testing and accurately recoding students' scores. The tester should therefore use tests that are fair, accurate and valid and also reliable for measuring the subject matter or construct the tests are supposed to measure. Learning cannot be directly measured but can be estimated through score of achievement test or other measures chosen.

Comparison of Experiments

An experiment begins with a researcher formulating a hypothesis, a statement predicting that the treatment will have a certain effect. The experiment is then arranged and conducted to test the stated hypothesis. Two groups of subjects are usually used in simple experiments representing the *experimental group* and the *control group* respectively. The experimental group is the one receiving a designated treatment while a control group receives no treatment. More often in educational research, comparisons are made of groups receiving different treatments, focusing more on the difference in the results of two or more treatments rather than on the results of one treatment versus no treatment at all. Comparison of a group or groups receiving treatment with an equivalent group with no alternative treatment makes it possible to draw reasonable conclusions from the results Before any valid comparison is made in experimental research, it must be ensured that experimental and control group(s) are equivalent in all variables that may affect the dependent variable except only in exposure to the independent variable. Such evaluative enquiry are made as whether there is a difference between the two groups or whether the effects of treatment A differs from that of treatment B. Answer to these are provided from comparison of group results.

Classification of Experimental Designs

Experimental designs can be classified into pre-experimental design, true experimental or quasi-experimental design, depending on the degree of control provided (Ary *et al*, 2002).

Pre – Experimental Design

The pre-experimental design provides little or no control of extraneous variables. It does not have random assignment of subjects to groups or other strategies to control extraneous variables. It is therefore considered a poor design even though it can illustrate quite well the way the extraneous variables may operate to injure the internal validity of a design. This design includes one-group Pretest Posttest Design, and Static Group Comparison.

One Group Pretest-Posttest Design

In this design only a single group is studied. It involves three steps.

(i) administering a pretest to measure the dependent variable; (ii) applying the experimental treatment to the subjects; (iii) administering a posttest, again to measure the dependent variable. Differences attributed to application of the experimental treatment are then evaluated by comparing pretest and posttest scores. The major disadvantage of this design is that the testee cannot attribute any change in scores to treatment administered since there is no control group. Extraneous variables may have taken toll on the subjects. The effect of pretest itself cannot be assessed. It therefore lacks internal validity.

Static Group Comparison

This design use two or more pre-existing or intact groups, only one of which is exposed to the experimental treatment. Subjects are not randomly assigned to groups and researcher assumes the groups are equal in all relevant aspects except only in their exposure to treatment. The dependent variable measures for the groups are compared to determine the effect of the experimental treatment. This design has control group(s) which permits comparison required for scientific respectability. The major limitation of this design is non-randomization or even matching in assigning subjects to treatment and control groups. It cannot be assumed the groups were equivalent prior to the experimental treatment. Any pre-existing differences may be responsible for observed change.

True Experimental Design

The designs in this category are so designated because subjects are randomly assigned to groups They also have control groups and include Posttest-only Control Group Design, Matched Subjects Posttest-Only Control Design, Pretest-Posttest control Group Design and Solomon Three Group Design.

Posttest-Only Control Group Design

(a) This design is one of the simplest yet, one of the most powerful of all experimental designs. It requires two randomly assigned groups of subjects. Randomization takes control of possible extraneous variable and assures that any initial differences between the groups are due to chance. In all other respects the groups are treated alike. Only one group is exposed to treatment after which the groups are measured on the dependent variable and scores compared to determine the effect of treatment. Any observed difference will be attributed to experimental condition and not to chance. This design controls for the main effects of history, maturation, regression and pretesting because not pretest is used. This design is very suitable for research in attitudes and also in studies in which a pretest is either not available or not appropriate, for example, in studies with kindergarten or primary grades where learning is not yet manifest. The design can also extend to include more than two groups if necessary.

(b) *Matched Subjects, Posttest-Only Control Group Design*

This is similar to Posttest-Only Control Group Design, except that it uses matching technique to form equivalent groups. Subjects are matched on one or more variables that can be measured conveniently, such as IQ or reading score. Matching is very useful where small samples are to be used and where Posttest Only Control Group Design is not appropriate.

(c) *Pretest-Posttest Control Group Design*

In this design, subjects are assigned to the experimental and control groups by random assignment and given a pretest on the dependent variable. The treatment is introduced to the experimental group for a specified time. The purpose of the control group is purely for comparison. Then the two groups are measured on the dependent variable. The average difference between the two groups is compared to ascertain whether the experimental treatment produced a greater change than the control situation. ANCOVA is used to determine statistical significance of the difference in gain scores. The main strength of this design is the initial randomization which controls most of the extraneous variable that pose a threat to internal validity. It also controls differential selection of subjects and statistical regression. This design can be used for more than two groups.

(d) Solomon Three Group Design
This design uses three groups with random assignment of subjects to groups. It has the advantage of applying a second control group and thus overcomes the problem inherent in the pretest posttest control group design – the interactive effect of pretesting and treatment. The second control group is not pretested but is exposed to treatment. Interaction effect is assessed by comparing the treatment scores for the three groups. Only posttest scores enter into the analysis.

Quasi-Experimental Designs

This is a popular alternative to the randomized experiment which like true experiments involves administering a treatment, but participants are not randomly assigned to treatment as in true experiments (Mitchell and Jolley, 2004). Designs that do not include random assignment are known as quasi-experimental designs. These designs are applicable where true experimental designs are not feasible. These designs permit the researcher to reach reasonable conclusions even though full control is not possible.

Nonrandomized Control Group, Pretest-Posttest Design

In a school situation where normal schedules cannot be disrupted nor classes reorganized to accommodate a research study, it is necessary to use groups as they are already organized into classes or other pre-existing intact groups. The tester can randomly select which group will be the control group and which will be the experimental group. It is not possible to know which of the two groups has done better before the study began. Thus, there is an initial selection bias that can threaten the internal validity of this design. But if there are no significant differences on the pretest, tester can eliminate selection as a validity threat. If there are some differences, the tester can use ANCOVA to statistically adjust posttest scores for the pretest differences.

There is also the *Counterbalanced Design* as a type of Quasi-experimental design. It can also be used for intact class groups, rotates the groups at intervals during the experimentation. The order of exposure to the experimental situation differs for each group. This design is employed where several treatments are to be tested but it can also be used with only two treatments.

Time Series designs: *One Group Time Series Design*

Another experimental design is the Time Series Designs which involves periodic measurement on one group and the introduction of an experimental treatment into the time series of measurement. X is introduced and additional measurements of Y are made. By comparing the measurements before and after, a tester can assess the effect of X on the performance of the group on Y. Time Series Design lacks a control group but uses continues checks to control internal validity threats. However, tester cannot rule out the possibility that it is not X but some simultaneous event that produced the observed change.

The Control Group Time Series Design is an extension of One Group Time Series Design to include a control group – an intact class.

Single-Subject Experimental Designs

This is an experiment run with a ample size of one. Obviously, there can be no random assignment or use of control groups. The single subject research had always had a place in educational and psychological research, for instance, in clinical applications or in observation of individual children, even, severely learning-disabled children.

There is also the *comparison of Single-Subject and Group Design* in which the tester examines the connection between the manipulation of independent variable and its effects on dependent variable.

Factorial Designs

A factorial design is a design which provides the researcher an opportunity for multiple comparison of the effect of more than one independent variable on a dependent variable. In complex social phenomena, several variables generally interact simultaneously. For example, the effectiveness of a particular method of teaching may depend on a number of variables such a ability level of students, personality of the teacher, classroom atmosphere, and so on. A one-variable design would not reveal the interactive effect of method and intelligence level but the factorial design would manipulate two or more variables simultaneously in order to study the independent effect of each variable on the dependent variable as well as effects caused by interactions among several variables.

There are two types of factorial design.

(a) In the first type, only one of the independent variable is experimentally manipulated. Here, the tester is interested in the effect of a single independent variable but must consider other variables that may influence the dependent variable such as gender, race, achievement, socio-economic status, intelligence and so on.

(b) In the second type, all the independent variables may be experimentally manipulated. The researcher is interested in several active independent variables to assess both their separate and combined effects. For example, a researcher might compare the effects of school location as well as class size on the learning of English grammar. Here, both variables would be manipulated, ie, school location and class size. This design permits analysis of main effects for both variables as well as for interaction between treatments.

Simple Factorial Design

Factorial design has been developed at varying levels of complexity. The simplest design is the 2 x 2 in which each of the two independents variables has two levels. For example, in comparing the effectiveness of two teaching methods on achievement it is believed there will be differential effects of the methods. Note that 2 x 2 design requires four groups of subjects.

Variable 2 (X_2)	***Variable 1*** (X_1)	
	Treatment A	Treatment
Level 1	Cell 1	Cell 3
Level 2	Cell 2	Cell 4

The tester examines the mean scores for the levels to determine the main effect of treatments, on achievement scores.

A factorial design also permits the assessment of *interaction* between the two independent variables, ie, the different effects of one of them at different levels of the other. The factorial design can be extended to more complex experiments, in which there are a number of independent variables. Theoretically, a factorial design may include any numbers of independent variables with any numbers of levels of each. However, when too many factors are manipulated or controlled simultaneously, the study and the statistical analysis become unwieldy and some of the combinations may be artificial, according to Ary *et al* (2002). The advantage of the factorial design are that it accomplishes in one experiment what otherwise might require two or more separate studies. But the complexities involved in handling large number of subjects under a large number of conditions has made most educational researchers attempt to answer their questions with the simplest possible designs.

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