UNIT 6 EXPERIMENTAL RESEARCH-I

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6.1 INTRODUCTION

In the previous Unit, you have learnt about various types of descriptive studies, where a researcher is expected to find out how differently the variables are related so as to understand the educational phenomena. But all these types may not help the researcher to establish a stable relationship among various variables in education. It is only through causal relationships that such relationships can be meaningfully understood. In order to study the causal relationship between the chosen variables, the researcher has to keep a check on other variables which may affect the relationship so studied. The way of checking the influence of other variables is known as Control. By applying controls a systematic and logical association between manipulated factors and observed effects can be established. How the hypotheses are retained or rejected in the light of the controlled variables –the answers to these questions can be found by understanding experimental research which provides for much control and therefore, establishes a systematic and logical association between manipulated variables and observed effects. In this unit, we shall discuss the concept of experimental design, how to ensure validity of experimental design and the role of controls in experimental design. In the next unit, we shall focus on different types of experimental design.

6.2 OBJECTIVES

After studying this unit, you should be able to:

- identify the characteristics of experimental research;
- define the concept of experimental design;
- find out different sources of error under any experimental research situation; and
- discuss different ways of bringing control in experimental research.

6.3 CHARACTERISTICS OF EXPERIMENTAL RESEARCH

Experimentation helps in establishing causal relationships among different events in educational situation under controlled conditions. Suppose a researcher wants to study the effect of the discussion method on the achievement of students. Here the main objective of the researcher is to know how the discussion method brings about a change in the achievement of students. This means that change in achievements is dependent on the discussion method. Hence achievement of students is the 'dependent variable' and 'discussion method' is the independent variable. In this example, there is only one identified dependent variable. It may, therefore, be inferred that during experimentation, the presence of both the independent variable and dependent variable is necessary. The number of dependent or independent variables may vary from problem to problem.

In the example given above, the researcher intends to study the effect of discussion method on the achievement of students. The discussion method is a deliberate operation of the conditions by the researcher. In the process of manipulation, a pre-determined set of varied conditions are imposed on the subjects selected for the experiment. The set of conditions is referred to as the independent variable, the experimental variable, or the treatment variable. In this problem achievement is not only influenced by the method of teaching but also by many other factors like intelligence, motivation, study habits, etc. All these variables may also influence the achievement of the students and interfere with the effect of discussion method on achievement. These variables are called as 'intervening variables'. When the effect of such intervening variables is checked, this is termed as controlling of variables. The number of variables to be controlled differs from problem to problem. During experimentation it is necessary to control the variables in order to study the effect of independent variables on the dependent variables. Various methods are used to control intervening variables which will be explained to you in the later part of this unit.

Again in the example, where the researcher is interested in studying the effect of discussion method on the achievement of students, the achievement is dependent variable. In other words, the dependent variable (a learning task) cannot be measured directly. The researcher can only estimate it through such measures as scores on a test. Strictly speaking, dependent variable (achievement of students), therefore, is scores on a test or observations with respect to some characteristics of the behaviour of the subjects used in the experiment. These, in other words, are called observations. Thus, during experimentation, observations (dependent variable) are taken as effect of the experimental or independent variable.

Moreover, no matter how objectively and carefully a researcher attempts to control the extraneous variables, still some discrepancy invariably remains and influences the results of the experiment. The researcher can take care of such discrepancies through the 'replication' of the study. For this, the same experiment has to be repeated several times at different places under similar conditions. Through the replications, the findings of an experiment conducted at different places under similar conditions are verified. If there is consistency in the findings of these replications, the generalizations are drawn. In other words, it may be said that experiments need to be repeated so as to verify the results, the consistency of which leads to generalizations.

To sum up it may be said that there are four essential characteristics of experimental research: i) control ii) manipulation iii)observation and iv)replication.

Control is the essential ingredient of experimental research as it refers to the extent to which different factors in an experiment are accounted for. Manipulation of variable is another distinguishing characteristic of experimentation. Observation and replication are the other characteristics of experimental studies.

Check Your Progress

Notes: a) Space is given below for writing your answers.

b) Compare your answers with those given at the end of the unit.

1. What is an experiment?

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2. Why do we need to control intervening variables?

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6.4 EXPERIMENTAL DESIGN

Suppose a researcher wants to find out the 'effect of reward on the achievement of students of grade VII'. To start with, the researcher will select a group of subjects on whom the experiment is to be conducted. This group may be taken, as it is, from the school setting or may be formed by an appropriate sampling procedure. Sometimes the researcher may like to have more than one group. This he can achieve by first selecting a group from the population and then forming two groups by randomly assigning the subjects to each of the group. From this exercise, the researcher has to take a decision beforehand as to how he selects the group or groups.

You know that the reward already exists in the classroom situation but not to the extent that its effect can be observed. So in the experimental setting, the researcher has to bring the reward in the classroom by increasing the intensity or frequency of the reward so that the subjects can feel its presence. Further rewards can be given in different ways like material reward, praise, and special remarks by the teacher etc. The way researcher wants to bring the reward in the classrooms needs to be specified in detail.

In a problem like this, the researcher starts with a hypothesis that there is a causal relationship between the reward and the achievement of the students. The researcher also knows that the achievement is also related with other variables like intelligence, achievement, motivation, extra coaching at home etc. These variables interfere during the experimentation and are termed as 'intervening variables'. Under such circumstances, the researcher would like to control the influence of such variables. There can be various ways of controlling the influence of such variables and the researcher decides about the ways to minimize or keep a check (control) over operation of variables which interfere during experimentation.

Sometimes, in order to control the intervening variables the researcher may have to identify and measure them. Apart from the measurement of intervening variables, the dependent variable (variable under investigation) has also to be measured so as to see what changes have been brought about by the treatment. The researcher has also to decide which instrument he is going to use to measure a particular variable. He must know which measuring instrument is available and which he will be constructing. The gathered data from measurements of dependent and independent variables are of a particular nature which are to be analyzed, keeping in mind the research questions.

From the above illustration it is clear that the researcher draws an outline or blueprint from the statement of hypothesis to the analyses of data for the experiment to be conducted. This outline constitutes the planning of the experiment. The planning of an experiment is called 'experimental design' encompassing aspects of strategy and structure. An experimental design is to the researcher what a blueprint is to an architect.

In the experiment of 'effect of reward on achievement of students' the researcher introduces a reward in the classroom for a specified period. At the beginning and at the end of the period the researcher may measure the achievement of the students. When the scores of the subjects obtained before and after the treatment are compared, one may find some shift in the scores of each subject. This shift may not be to the same degree in all the subjects within that group. The larger the shift from the initial standing, the more pronounced will be the effect of the treatment. The shift of the individual's position on dependent variable within the group is termed as 'variance'. The shift that can be mainly attributed to the treatment is termed as 'Treatment Variance'.

As already stated, during the treatment, factors like intelligence, extra coaching at home, achievement motivation etc. may also operate and change the scores of students on an achievement test administered at different points of time. The shift in position of each subject within the group will take place not because of the treatment alone but because of the other factors also. But the researcher may attribute this entire shift to the treatment. Under such circumstances, one may say that the researcher has, by mistake, attributed the entire shift in positions to the treatment. Thus, whenever the effect of intervening variable is mistaken to be that of treatment, then such an mistake or error is termed as 'Error-Variance'.

In the example under discussion, if the researcher continues his experiment under the influence of intervening variables, the shift in position of subjects within the group will reflect the combined effect of treatment and intervening variables. Since the researcher is interested in finding out the effect of treatment (reward) on the dependent variable (achievement), he has to check that the intervening variables do not operate during the process of experimentation. In short, it may be said that the researcher is trying to reduce the effect of intervening variables or minimizing the error variance. When the error variance is reduced, the finding will reflect the shift in position of the subjects mainly because of treatment i.e., treatment effect will be more prominent leading to the maximization of treatment variance. The researcher therefore, has to plan the experiment in such a way that treatment variance is maximized and error variance is minimized.

The main objective of planning an experiment is to maximize the treatment variance and minimize the error variance. This, in other words, is termed as 'Validity' of experimental design.

The purpose of experimental design therefore is to find out true effect of the treatment. Any experimental design, when it measures what it purports to measure (true effect of treatment) is a valid design. Its validity is hindered by various factors during the experimentation. By putting a check over the effect of such factors, the researcher can increase validity of a design i.e., a researcher tries to make certain, through putting checks that these variables have not produced any such effect that can be mistaken for the effect of treatment.

6.5 VALIDITY OF EXPERIMENTAL DESIGN

Putting a check or control on the factors that give rise to error can minimize error variance. In order to control these factors the researcher ought to know these at the time of designing an experiment. In other words, he should know the factors or the sources that are responsible for error. Campbell and Stanley (1963) have identified some such sources of error. These have been listed as – History, Maturation, Testing, Instrumentation, Regression, Selection, Mortality, Interaction of selection and maturation, Interaction of testing and treatment, Interaction of selection and treatment, Reactive arrangements, and Multiple treatment interference. All these sources of error are related to the internal validity of the experimental design. In the proceeding frame the sources of error have been dealt with in detail.

In order to explain sources of error, let us take an example. Suppose a researcher wants to study the effect of a remedial programme on the achievement of tenth grade students in mathematics. At the beginning of the session he selects a group of 100 students. All these students have got low scores in mathematics in their school examination. These students are given the remedial programme for a period of six months. Before and after participation in the remedial programme these students are given an achievement test in mathematics developed by the researcher. On analysis the researcher finds that there is a great shift in the scores of students from the initial scores in mathematics. He may attribute this shift in scores to the treatment. Let us try to understand on the basis of error variance if the conclusions drawn by the researcher are right.

6.5.1 Internal Validity

History

From the example presented in the block above, it is evident that the treatment is extended over a period of six moths. You know that the remedial programme (treatment) is not a regular feature of the school teaching programme. During the treatment period it may happen that extra lectures are arranged by some person in the school or students or staff members may go on strike, or some activities are organized by the school mathematics club, or an excursion trip is arranged by the school, etc. All these special events may directly or indirectly affect the achievement of students in mathematics. The researcher never wanted to study the effect of such special events that counted for part of the achievement gains. The researcher may mistake the whole gain in achievement in mathematics for the effect of remedial programme. Such special events that affected the dependent variable (achievement in mathematics) and brought in error are called as 'History effect'. The researcher should try to control such special events that may occur between the first and the second measurements of the subjects that affect the dependent variable.

Maturation

While the experimental treatment is in progress, biological and psychological changes are likely to occur. The time period that elapses during the experimentation may produce certain changes in the subjects. For example, the subjects may perform differently on the dependent variable on different occasions as a result of biological or psychological processes like fatigue, age, interest or motivation. Therefore, the effect of such changes on the dependent variable along with treatment may bring in error called as 'Maturation effect'.

Pre-testing

The students in the example given in the box have been tested before and after the treatment. The testing process before the treatment is called Pre-test and after the treatment is called Post-test. The exposure of the subjects to the pre-test may serve as the learning experience and therefore it may affect their post-test performance. The shift in position may therefore be because of treatment as well as the pre-test learning experience. The experience of students gained because of pre-test affects their achievement in post-test and brings in an error called 'Testing effect'.

Measuring Instruments

Different measuring instruments, scorers, raters, interviewers or the observers used at the pre-and post-testing stages may also account for the observed differences in the scores or measures of the dependent variable. In the example under discussion, it is quite possible that the test used at the pre-test stage may be more difficult than the

test given at the post-test stage. This means that the test used in the two testing stages may differ in their difficulty levels. On analysis the researcher may find a shift in student's achievement. The shift in reality can be attributed to the measuring instrument rather than treatment. In this way error may be caused because of different natures of the measuring instrument.

Statistical Regression

In the example under discussion you have observed that only those students were selected who did poorly in school tests. So this group is chosen on the basis of extreme scores, that is, poor performance in mathematics. The mean score of this group will tend to move towards the mean of the parent population on the second test whether or not an experimental treatment is applied. It may cause a statistical regression effect. This refers to the tendency for extreme scores to regress towards the common mean on subsequent measures. Such a tendency may operate to produce an effect that could be interpreted as an effect due to experimental treatment. The shift in scores on dependent variable may be mistaken for the treatment effect. In this way error is caused due to the tendency of extreme groups to move towards the mean. This is called 'Regression effect'.

Differential Selection of Subjects

The groups may differ significantly on some important variables related to the dependent variable even before the application of the experimental treatment. If the researcher had taken two different groups instead of one in the example given in the box, there was every possibility that these groups equivalent with respect to sex, previous school achievement, socio-economic status, intelligence etc. may not be similar with respect to many other intervening variables like mathematical ability, numerical aptitude, liking for mathematics etc. In such a case, non-equivalency of groups, creeping in due to difficulty in selection procedure, may affect the variable under study. The shift in scores on dependent variable may be mistaken for treatment effect. The error like this is caused due to selection procedure. This is called 'Selection' effect.

Experimental Mortality

If, for example, some subjects in the experimental group who receive the lowest scores on the pre-test drop out after taking the test, this group will show a higher mean on the post-test than the control group, not because of the experimental treatment but because the low scoring subjects dropped out of the study. The differential loss of subjects from the comparison groups may affect the findings of the study. The dropping out of the subjects during experimentation is called 'Mortality'. Thus mortality is one of the sources of error in experimental design.

Interaction of Selection and Maturation, Selection and History

Till now you have studied various sources of error like history, maturation, pre-testing, measuring instrument, statistical regression, differential selection of subjects, and experimental mortality. But all these do not exist in isolation-rather all these occur simultaneously during experimentation. For instance in the example under study, there is every possibility that after the treatment on post-testing, the group wherein interaction of numerical aptitude and special lecture has taken place achieves high scores. Such interactions of selection and history may boost the scores on dependent variable even in the absence of treatment. In the same way, other factors may interact among themselves and influence the dependent variable. Under such circumstances, the researcher may mistake the gain or shift in scores on a dependent variable for treatment effect. Thus interaction of selection, maturity and history etc. are some of the sources of error.

From the discussion in the foregoing pages, it may be said that the internal validity of an experimental design depends on factors like history, maturation, testing, instrumentation, regression, selection, mortality and interaction of selection and maturation etc. Along with it there is another important objective of the researcher, that is, to determine whether the systematic relationships that have been identified, isolated and measured can be generalized outside the experimental setting.

6.5.2 External Validity

The extent to which the objective of the researcher is attained is a measure of the 'external validity' of the experimental design. This validity is concerned with the generalizability. Braacht and Glass (1968) have classified external validity into two types: (i) population validity and (ii) ecological validity.

Population Validity

Population validity is concerned with the identification of the population to which the result of an experiment can be generalized. For instance, in the example under discussion the researcher has studied the effectiveness of remedial teaching in mathematics on a sample of tenth grade students in Punjab and found that remedial teaching helps in gaining scores. From these results, the researcher would like to conclude that remedial teaching is helpful for the groups of tenth grade students in Punjab. In order to make valid generalizations from the experimental results to larger populations, the researcher must correctly identify populations to which the results can be generalized. For this the researcher has to make a distinction between the experimentally accessible population and the target population. The former refers to the population of subject that is within the reach of the researcher for his study. The latter is the total group of subjects to whom he wants to apply the conclusions from the results of his experiment. In the example, all the tenth grade students studying in high schools of a particular district where the experiment has been conducted may be the experimentally accessible population. The target population would be all tenth-grade students of the State. The generalizations of the study would be done in two phases: (i) from the experimental sample of tenth grade students to the experimentally accessible population (tenth grade students of all secondary schools of the concerned District), and (ii) from the accessible population to the target population (tenth-grade students of all high schools of the State).

If the researcher has strictly followed the principal of randomization in selecting the experimental sample from the experimentally accessible population (tenth grade students in the high schools of the District), he can generalize the findings to this population with no difficulty. For this the researcher has to specify the accessible population by listing and numbering its every member and then select the sample through the use of random numbers of any other random procedure.

Generalizations from the accessible population to the target population are somewhat risky and cannot be made with the same degree of confidence as the former type. For such generalization, the researcher must have a thorough knowledge of the characteristics of the accessible and target population. If the characteristics of both the populations are similar, the researcher can generalize the results with more confidence. In the example under discussion, if the researcher has randomly selected his experimental sample from all tenth grade students of a District, then the accessible population would be more like the target population (all tenth grade students of the State) and the findings could be generalized to the target population with much more confidence. When the researcher attempts to generalize from the accessible population to the target population, it is important for him to know that one is similar to the other with respect to certain significant and relevant characteristics.

The interaction as the result of "selection by treatment" also contributes to population validity. When a researcher selects two experimentally accessible populations and these are not representative of the same target population, the similar studies on two accessible populations can lead to entirely different results. In other words, an interaction that may occur between the treatment and the characteristics of one experimental sample selected from one accessible population would not occur in another experimental sample selected from the second accessible population with different characteristics. Therefore, it would not be possible for the researcher to generalize the findings from one sample to another (Koul, 1988).

Ecological Validity

In addition to population validity, the researcher should also be concerned with ecological validity. It is concerned with generalizing experimental effects to other environmental conditions. Ary et. al. (197, p. 235) suggest that "to have ecological validity, a design must provide assurance that the experimental effect is independent of the particular experimental environment".

According to Koul (1988), the authors are of the opinion that the researcher must give increased attention to the following factors for achieving ecological validity:

i) The researcher must furnish a complete description of the operations and the experimental setting involved in the experimental study. It helps a reader to judge to what extent the results can be generalized to other situations. In the example under discussion the researcher has studied the effectiveness of remedial teaching in mathematics on tenth grade students under certain experimental conditions. The findings would not be applicable to other subject areas of the same grade, unless the study is extended to a variety of teaching situations. One may ask if the findings of the study would be the same if a school in a rural setting was used instead of an urban school in a replication of the study, and so on.

ii) The researcher must give due consideration to the experimental arrangements while generalizing findings of the study. There may be a reactive effect due to the experimental procedures. The presence of observers, experimental equipment and knowledge of participation of the subjects in an experiment make the subjects aware of the fact that they are receiving experimental treatments and, therefore, they may change their normal behaviour. Such a change is called 'Hawthorne effect'. If subjects change the behaviour that is being measured, the researcher cannot claim that the effect of treatment variable for the same population will be the same for subjects who are exposed to the treatment variable in non-experimental situations.

iii) Another concern in ecological validity is the question of the representativeness of the independent or experimental variables and dependent or criterion variables. Variable representativeness influences the generalizability of the findings of an experimental study. For example, when a researcher speaks of remedial teaching, he will have to clarify what kind of remedial activity he means.

iv) Certain interaction effects may also influence the generalizability of experimental findings. When two or more treatments are administered to the same group within the same or different studies, it is difficult to find the cause of the experimental results or to generalize the results to the experimental settings in which only one treatment is present. In some situations, a pre-test may increase or decrease the sensitivity or responsiveness of experimental subjects to the independent or experimental variable and, therefore, findings obtained for this pre-tested population cannot be generalized for the un-pre-tested population from which the experimental subjects were selected.

v) The tools or instruments used for the measurement of dependent variable also contribute to the ecological validity. For instance, if a researcher uses an essay type test to measure academic achievement (dependent variable), can one say that the same effect would be observed if an objective type test was used as the measure of the dependent variable?

In short it may be said that experimental design is blueprint of the experimentation in educational research. The validity of the experimental design depends upon the achievement of major objectives of the experiment. The researcher must select a design that is strong both in internal and external validity. However, in certain educational experiments, one type of validity can be obtained at the cost of another one. In such cases, the researcher should attempt to reach a compromise between two types of validity, i.e. he should choose a design, within practical limits, that provides sufficient control to make results interpretable and generalize findings to the intended settings.

Check Your Progress

Notes: a) Space is given below for writing your answers.

b) Compare your answers with those given at the end of the unit.

3. How can an experiment design be internally and externally valid?

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4. What are the main objectives of an experimental design?

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6.6 CONTROLS IN AN EXPERIMENT

By now you have understood different factors affecting the internal and external validity of an experimental design. In order to make experimental design both internally and externally valid, a check has to be put on the sources of error affecting dependent variable. This is called 'Control'. For example a researcher wants to compare the instructions through Programmed Learning Material (PLM) with the conventional teaching in terms of achievement of tenth grade students. You know that achievement is affected, apart from teaching methodology, by intelligence, study habits, socio-economic status, school climate etc. In order to ascertain the effect of an independent variable on the dependent variable, it is necessary to check the influence of these other or extraneous variables. This aspect of experimental design is called as 'Control'. There are various ways of instituting control. Suppose a researcher wants to put a check on or control intelligence and gender in an experiment, he can form and select the groups in such a way that each group gets equal number of male and female students. Similarly, he can have students in each group with matching intelligence. In this way groups can be made similar with respect to gender and intelligence. But if the researcher is compelled to have similarity with respect to another intervening variable say socio-economic status, it may not be that easy. Under such circumstances, the researcher may adjust the achievement of students with their socio-economic status with the help of statistical technique called 'Analysis of Covariance'. You will study about 'Analysis of Covariance' in Unit 15 of Block 4. From this example, it may be said that intervening variables can be controlled by employing different procedures. These procedures may be physical manipulations, selective manipulations or statistical methods.

6.6.1 Purpose of Control

Van Dalen (1973, pp. 263-364) has pointed out that in an experiment, the researcher seeks to control variables for the following purposes:

1. **Achieving Isolation:** To prevent a factor other than the independent variable from affecting the dependent variable, the researcher may remove the unwanted or interfering variable, or he may keep its effect constant or equalize its presence in the experimental and control groups.
2. **Achieving Changes in Magnitude:** A researcher may strive not only to isolate the independent variable but also to ascertain how much effect it contributes. To achieve this objective, he may try to vary the magnitude of the experimental variable.
3. **Achieving Quantitative Evaluation:** The ultimate goal of a researcher is to express the magnitude of the variable in quantitative terms. He may be interested to know not merely that one expression of a variable is larger or smaller than another but precisely how much larger or smaller it is. If two variables are functionally related, he may desire to state not merely that they are positively or negatively related but rather the specific degree of relationship in terms of some numerical value.

A high degree of control is much easier to achieve in the laboratory setting than in the situations outside the laboratory. In the laboratory, the researcher deals with a limited number of factors and he can manipulate the conditions at will. He can be sure of the changes that have taken place and within a limited amount of time he can measure the effects with greater precision.

6.6.2 Methods of Control

In experimental studies in education, the researcher has to direct his effort towards controlling the variables which are significantly related to the dependent variable. Such variables are responsible for any relevant pre-existing differences between the subjects used in the experiment. In addition to inter-subject differences, there are some situational variables that might operate in the experimental situation itself. If the relevant and situational variables are not controlled in an experiment, the researcher cannot be sure whether these are independent variables or incidental differences operating in the groups that are producing the difference in the dependent variable.

a) **Random assignment of subjects to groups**: Let us say, a researcher wants to compare auto-instructional method with the conventional method of teaching mathematics in terms of achievement of tenth grade students. He takes a school where two sections of class ten are available. These groups may have initial differences with respect to intelligence, interest, achievement motivation, study habits, etc. These variables affect the achievements. If a researcher exposes one section to the auto-instructional method and other to the conventional method, the achievement of two groups is bound to differ. This difference may not be solely due to the treatment but because of other variables (already mentioned). In order to find out the true effect of the treatment (method of teaching), there is need to control the above mentioned variables. The best alternative available with the researcher in such a situation is to randomly assign objects (subjects, treatments, groups) of a universe in such a way that, for any given assignment to a subset, every member of the universe has an equal probability of being chosen for that assignment. Since, in random procedures, every member of a population has an equal chance of being selected, members with certain distinguishing characteristics —male or female, high or low intelligence, and so on will have equal probability, if selected, will probably be counterbalanced in the long-run. In

other words, the achievement of both the groups will be affected by intervening variables to the same extent because they are similar. On comparing the mean achievement of students of two groups, the effect of intervening variable will be nullified. Here it may be elaborated that randomization does not eliminate error, but only transforms constant error (bias) to random error that can be estimated through statistical estimation process. This means that assigning the subjects randomly to the groups can control the effect of intervening variables.

b) **Matching subjects with random assignments:** Another method that is used for assigning subjects to groups is to match individual subjects on extraneous variables. For this the researcher can identify variables that might affect the dependent variable and then apply some random technique to assign one member of each matched pair to the groups. The researcher, for example, in the preceding illustration may match the subjects on the pre-achievement scores in mathematics/ or any other variables that are known to have an effect on the dependent variable, such as scores on an intelligence test or an aptitude test in mathematics, achievement motivation test, or socio-economic background. Then one member of each pair may be randomly assigned to any of the two groups.

The researcher may encounter several difficulties while matching subjects. The first and the most important of these is to determine what variable or variables are significantly related to the dependent variable and which of these to use as a basis of matching. Variables such as intelligence, socio-economic status, sex, age, achievement motivation, pretest scores on the dependent variable, etc. are commonly used as the basis for matching. The experts are of the opinion that the variables on which subjects are matched must correlate as high as 0.50 or more to the dependent variable.

Another problem that may be faced by the researcher is how closely to match the subjects on the variable or variables. If he/she matches the subjects closely, it increases the precision of the method at the cost of reducing the size of sample and increasing sampling bias into the study.

Generally three matching procedures are used in experimental studies. Keeping in view his/her situation, the researcher has to decide what matching procedure is feasible in a particular situation.

i) **Procedure of subject-to-subject matching**: In subject-to-subject matching, the researcher seeks to locate two members from the available subjects whose scores are within the limits and then he/she decides upon matching them. For example, suppose the researcher selects socio-economic background as the matching variable, and then he may identify two subjects who are within 3 points of each other on the socio-economic background as the matching variable, then he may identify two subjects who are within 3 points of each other on the socio-economic status scale, and then randomly assigns one member of the pair to one group and the other member to the other group. It is always possible to match subjects on one variable. However, if there are two or more than two relevant variables, then it becomes extremely difficult for the researcher to find pairs who match on all such variables, and, therefore, most of the subjects are not selected for the study. This shows restrictiveness of the matched pair method as a technique of control.

ii) **Matching for mean and standard deviation:** To overcome the problems of subject-to-subject matching, sometimes it is worthwhile to match groups rather than individuals on the relevant variable or variables. In such a situation the researcher seeks to show that the two groups do not differ significantly in terms of mean and standard deviation on the matching variable or variables. For example, if in an experimental study, intelligence, socio-economic status and achievement motivations are considered the relevant matching variables, the researcher may analyze the scores on the intelligence test, socio-economic status scale and

achievement motivation test, and try to ensure that there is no significant difference in the means and standard deviations of the scores on the selected tests. The researcher then randomly assigns the groups to two experimental conditions. Some experts are of the opinion that matching on the basis of groups is less precise in comparison to individuals matching. Moreover, the researcher may have a problem in identifying the groups that match on all of the variables that may be correlated with the dependent variable. However, it is important to note that if the two groups stand very near in respect of the indices of central tendency and variability, group equivalence seems to have been achieved. You will study on central tendency and variability in Unit 14 of Block 4.

iii) **Ranking of subjects on the matching variable:** A third method of matching is to place all the available subjects in rank order on the basis of their scores on the matching variable. Regardless of the actual difference, the first two subjects are selected from the rank order list and these constitute the first pair. One subject of this pair is then randomly assigned to one of the groups and the other to the second group. Similarly, the next two subjects on the rank order list are chosen and again one is randomly assigned to the first group and the other to the second group. This method is also less precise than that of the subject-to-subject matching.

c) **Holding intervening variable constant:** Another procedure that is used to make groups comparable on an extraneous variable is to hold the intervening variable constant throughout experimentation. For example, if a researcher is confident that gender is a variable that might affect the dependent variable, then he/she could select a subject of a particular gender by selecting only male students, for experimentation. This way the researcher would be able to control the effects of sex as an extraneous variable. Similarly, if socio-economic status is likely to be a variable that may affect the dependent variable of the study, the researcher could select subjects within a restricted range of the effects of socio-economic status. By this method the researcher is able to control the effects of socio-economic status. After selecting the subjects from the homogeneous population, the researcher could randomly assign subjects to two groups and be confident that the groups were comparable on the relevant variable. Although the selection of subjects from the homogeneous group is useful in eliminating the problems of subject-to-subject matching, it has the disadvantage of decreasing the extent to which the results can be generalized beyond some situation. If a researcher studies the effect of auto instructional material on the sample of English medium male students, the findings of such a study cannot be generalized for the students of the mother tongue as a medium of instruction. For such generalizations the researcher will have to repeat studies with students from another medium of instruction.

d) **Method of using subjects as their own controls**: Another method of control is to assign the same subjects to two experimental treatments and then to obtain measurements of the subjects first under one treatment and then under the other. Although this method is an efficient method of control, it is not feasible in certain circumstances. A researcher, for example, is interested to know the difference in learning time between two different lists of nonsense syllables — one list with high association value and the other with low association value — in an experiment on retention. In such an experiment, the researcher can find the difference in learning time between two lists for each subject and then test the average difference in learning time for all subjects with the help of an appropriate statistical test for significance. But the effects of relative case of learning the two lists, fatigue, and other interference effects cannot be partialled out completely and no reliable conclusions could be drawn. Moreover, in some studies the researcher while exposing the subjects to one experimental condition cannot use them for

the other experimental condition. In teaching some material using two different methods, for example, a researcher cannot teach the students with one method and then make them to forget the first one to expose them to another.

e) **Method of Counterbalancing**: If the same treatment is rotated amongst various groups it is called counterbalancing. It helps in controlling sequencing and carryover effects that arise when a group is exposed to multiple treatments. The counter balancing can be achieved by three ways, namely complete counter balancing, incomplete counterbalancing and randomized counterbalancing. When all possible combinations of treatment are given to groups, it is called complete counterbalancing. Its applicability gets limited when there are large number of treatment combinations. In case of incomplete counterbalancing only those treatment combinations are selected where each treatment appears equal number of times in each ordinal position. It requires as many groups as is the number of treatments. While applying random counterbalancing, the researcher selects randomly the number of treatment combinations as per the number of available groups. The researcher assigns treatment combinations randomly to the groups. It controls the sequential and carryover effect of treatments through assumptions underlying randomization.

f) **Methods for Controlling Situational Variables:** In any experiment, three things are involved. These are – environment of experimental setting, subjects involved in the experiment and the treatments used in the experimental procedure. The variables related to these intervene in the process of experimentation. The intervening variables related to environment of experimental setting are controlled through physically manipulating them.

There are three methods commonly used to control situational variables. One is 'the Method of holding situational variables constant'. In this method the researcher treats all the available subjects alike except for their exposure to the independent variable. For example, in a reading experiment the researcher may take equal number of subjects in two groups, teach them by the same teacher, and use the same instructions, apparatus, and tests. The groups may be taught in the same classroom and at the same time of the day, in the same environmental conditions such as temperature, presence or absence of distracting noise, furniture in the room and the like. A second way is the 'Method of randomization'. If the situational conditions cannot be treated alike, the researcher tries to balance them by randomization. Suppose in the study mentioned above it is not possible to have the same teacher for both the groups. Then the researcher may divide the two major groups into two smaller sub-groups and randomly assign half the subjects of the first major group and half the subjects of the second major group to each teacher. The same procedure could be used to randomize other situational variables like time, apparatus and tests. The third method is systematically manipulating the situational variable. In some educational experiments, the researcher can use sequences of experimental and control conditions in order to control what Ary et. al.(1972, p. 227) have called 'progressive effects' like those of practice and fatigue. This, according to them, can be done by "controlling the order in which experimental conditions are presented through a counter-balancing; half the subjects may receive an AB order and the other half a BA order."

g) **Applying statistical control**: Theoretically, the researcher can control the effect of variables like sex, soio-economic status, aptitude, intelligence, etc. through physical manipulation and selective manipulation. But in practice it is vary difficult to control all the variables since it affects the sample size. Under such conditions it is advisable to control some intervening variables by physical manipulation, some by selective manipulation and others by statistical procedures. When the intervening variables can be held constant through the use of statistical techniques,

this is called statistical manipulation. There are two statistical techniques commonly used to hold variance constant. These are analysis of co-variance and partial correlation. You will study about analysis of co-variance and partial correlation in unit 15 of Block 4.

The technique of analysis of co-variance is used to control the variation within the groups. This technique analyses the differences between the two groups, subjects the two to different experimental treatments on the dependent variable after taking into account any initial difference between the groups on pretest measures or any other relevant independent variables. In the analysis of co-variance, one or more co-variances can be used in addition to the dependent variance. But while using analysis of covariance the researcher has to be careful that data of the experiment fulfil the assumption of homogeneity of variance. If the data do not fulfil the assumption of homogeneity, then the data can be analyzed with the help of Multiple Regression Analysis. In such cases the dependent variable scores are taken as the criterion variable and independent variable scores are taken as the predicting variable. This analysis helps in finding out whether the treatment variable significantly improves prediction. In order to understand analysis of co-variance and multiple regression equation, you are advised to study Unit 15 of Block 4.

Let us take up a case where the researcher wants to study the effect of previous teaching experience on teaching competency of teachers. The survey of research supports the theory that teachers' attitude towards teaching is related to teaching competency and teaching experience. Under such circumstances, the true relationship between previous teaching experience and teaching competency cannot be found out without partialling out the effect of attitude towards teaching. This can be accomplished by using statistical techniques known as Partial Correlation.

In short it may be said that physical manipulation, selective manipulation and statistical manipulation can control the intervening variables. Physical manipulation can be accomplished by eliminating the intervening variables. Under selective manipulation comes randomization, matching and counterbalancing. The third technique of control is statistical manipulation, where the intervening variables are held constant by statistical techniques like analysis of covariance and partial correlation.

Check Your Progress

Notes: a) Space is given below for writing your answers.

b) Compare your answers with those given at the end of the unit.

5. What is the purpose of employing controls in an experimental study?

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6. List the techniques used in selective manipulation.

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6.7 LET US SUM UP

In this Unit, we started our discussion with the concept of experimental research which primarily aims to establish causal relationship among different events in educational situation, under the controlled conditions. While conducting experimental research, different kinds of variables which play significant roles in influencing the cause-effect relationship were also discussed. In order to carry out experimental research, the researcher has to adopt an experimental design which is an outline or

blueprint from the statement of hypotheses to the analyses of data for the experiment to be conducted. Experimental design has to be validated against internal and external criteria / factors. In order to ensure internal and external validity to the experimental design, a check or control has to be put on the sources of error effecting dependent variable. We discussed different purposes and methods of controls.

6.8 UNIT-END ACTIVITIES

Identify/select any five M.A. (Education) / M.Ed. dissertations using experimental research design. Find out the following:

i) Types of variables used in the experimentation - Independent, Dependent and Intervening variables.

ii) Types of controls adopted by the researchers in conducting the researches.

6.9 POINTS FOR DISCUSSION

1. Is it possible to find out the true effect of the treatment in experimental research? Justify your answer.
2. Discuss the merits and demerits of experimental research in studying human behaviour in educational phenomena.

6.10 SUGGESTED READINGS

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6.11 ANSWERS TO CHECK YOUR PROGRESS

1. Experimentation is the process of establishing causal relationship among different events in educational situation under controlled conditions.
2. Alongwith independent variable, intervening variables also influence the dependent variables. In order to know the exact impact of independent variable on the dependent variable, it is necessary to control the intervening variables.

3. While conducting experimental research, a researcher has to control the factors that affect the internal validity. These factors are history, maturation, testing, instrumentation, regression, selection, mortality and interaction of selection and maturation. The experimental research is also to be externally validated. This means the result of an experiment can be generalized to a wider population, which is concerned with population validity and to other environmental conditions, which is concerned with ecological validity.
4. The main objective of experimental design is to maximize the treatment variance and minimize the error variance. In other words, it is to find out true effect of the treatment on the dependent variable.
5. The purposes of employing control variables in the experimentation are the following:
   a) To prevent a factor other than the independent variable from affecting the independent variable.
   b) To vary the magnitude of the experimental variable to ascertain how much effect it contributes.
   c) To find out the degree of relationship between two variables in terms of some numerical value.
6. a) Randomization
   b) Matching
   c) Counterbalancing.