CHAPTER ... POOR

DESIGN OF THE STUDY
CHAPTER FOUR

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STUDY

The purpose of experimentation is generally understood as establishing a functional relationships among phenomena by constructing the occurrence of certain outcomes under controlled conditions designed to prevent the confusing effects of the operation of extraneous factors (Mouly, 1963). Stated differently, the important intention in experimentation is to describe the effects of certain treatments upon some characteristics of defined population and to test some hypotheses about this effect. Again, for conducting an experiment, it is not only necessary to consider how to describe and measure the desired effect, but also how to test its significance.

The main purpose of the present study was to study the effectiveness of step-size in relation to three levels of taxonomic categories. For this, it was necessary to construct a suitable research design or specification of operations for testing hypothesis. This chapter, therefore, discusses the plan for experimentation - the methodology and procedure adopted including the nature of the sample and the experimental design followed for verification of hypotheses and the statistical techniques employed.
METHODOLOGY

In the present study, experimental method was used since the purpose was to examine the relationship between variables: step-size, taxonomic category, and sex. From an operational point of view, experimentation is a matter of varying the independent variable in order to study the effect of such variation on the dependent variable. Variables may also be spoken as factors. Independent variable, according to Tuckman (1972), is that factor which is measured, manipulated, or selected by the experimenter to determine its relationship to an observed phenomenon. An independent variable used in an experiment may be either a treatment variable or a classification variable. Ferguson (1971) defines a treatment variable as one that involves a modification in the experimental subjects, a modification which is controlled by the experimenter. This involves direct control since in this case the experimenter deliberately manipulates a treatment variable by setting its levels at pre-determined values for groups of experimental subjects, for example, two step-sizes in programmed instruction.

In effect, the subjects are treated in some way by the experimenter. Experimental subjects may, however, be classified in a characteristic which was prior to, and quite apart from, the experiment,
and does not result from the manipulations of the experimenter. Such a variable is a classification variable. In the case of classification variable, the experimenter exercises indirect control since he makes use of a prior categorisation for experimental grouping. An example of this is grouping according to sex of experimental subjects. This distinction, although useful from a general design point of view, has no substantial bearing on the analysis of experiments. That is, it is generally statistically irrelevant whether the treatment variables are manipulated or selected, or some mixture of these types is involved.

Mitchell Dayton (1970). The effectiveness of the treatment is determined by the amount of attainment recorded by the subjects. The criteria by which a particular condition or treatment is evaluated are called dependable variables (Fox, 1967). The dependable variable is that factor which is observed and measured to determine the effect of the independent variable (Tuckman, 1972).

In the present study, step-size, sex and taxonomic category constituted independent variables and measures of students' achievement - scores - as dependent variables. Further, step-size and taxonomic category might be termed treatment variables and sex as classification variable.
Experiments designed to study simultaneously the effects of two or more independent variables are termed factorial experiments. Within the factorial design, it is possible to assess the effect of each independent variable separately as well as their joint or simultaneous effects (Tuckman, 1972). In this study, a factorial experiment with three factors viz., step-size, sex and taxonomic category having 2, 2 and 3 levels respectively, was employed. It may be mentioned that the treatments involved in taxonomic category have been administered to the same subjects, but it is not true of sex and step-size. Thus a "mixed" factorial design was used in this experiment.

A mixed design may be defined as one in which some of the treatment comparisons are inter-subject and some are intra-subject (Lindquist, 1956). Mixed design may be regarded as mixture of the simple randomised and the treatment X subjects design. In the present factorial experiment the main effect of taxonomic category and all interactions involving it are "within" effects, while the main effects of step-size and sex and the interaction involving these are 'between' effects.
The dimensions of a factorial design refer to the number of factors and the numbers of levels within each factor. As already indicated, independent variables are called factors and the number of ways in which a factor is varied is called the number of levels of the factor. In this experiment, the first factor is step-size which is varied in two ways: by presenting the material in small steps and by presenting the same material in large steps. The second factor is sex and this is obviously available in two ways—boys and girls. The third factor is the taxonomic category. This factor is taken at three levels corresponding to Bloom’s three taxonomic categories in the cognitive domain—knowledge, comprehension and application.

A factorial design is labelled in terms of the number of levels of the factors involved. The present factorial experiment may, thus, be termed as a $2 \times 2 \times 3$ factorial experiment. For simplicity and clarity the three factors have been coded A, B, C and their levels as $A_1, A_2; B_1, B_2$ and $C_1, C_2$ and $C_3$ respectively. $A_1$ and $A_2$ correspond to small step and large step, $B_1$ and $B_2$ designate two levels of sex—boys and girls, while $C_1$, $C_2$, $C_3$ represent three levels of taxonomic categories. The $2 \times 2 \times 3$ factorial design is schematically represented in Table 37.
TABLE 37
SCHEMATIC REPRESENTATION OF THE 2x2x3
FACTORIAL DESIGN

<table>
<thead>
<tr>
<th></th>
<th>A₁</th>
<th></th>
<th>A₂</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>B₁</td>
<td>C₁</td>
<td>B₂</td>
<td>C₁</td>
<td></td>
</tr>
<tr>
<td>B₂</td>
<td>C₂</td>
<td>B₁</td>
<td>C₂</td>
<td></td>
</tr>
<tr>
<td>B₃</td>
<td>C₃</td>
<td>B₁</td>
<td>C₃</td>
<td></td>
</tr>
</tbody>
</table>

The two levels of factor A
and two levels of factor B have been used in combination
with each of the three levels of factor C which have
given rise to 12 treatment combinations. Twelve treatment
combinations used in this experiment are given in Table 38.

TABLE 38
TREATMENT COMBINATIONS OF 2x2x3 DESIGN

<table>
<thead>
<tr>
<th></th>
<th>A₁</th>
<th>B₁</th>
<th>C₁</th>
</tr>
</thead>
<tbody>
<tr>
<td>A₂</td>
<td>B₂</td>
<td>C₂</td>
<td></td>
</tr>
<tr>
<td>A₃</td>
<td>B₃</td>
<td>C₃</td>
<td></td>
</tr>
</tbody>
</table>

SAMPLING
This study covered the target
population of grade VI students, numbering about 1000, of
ten secondary schools in Siala. Owing to obvious constraint
of the field situation, it was not considered feasible to
encompass the entire accessible population. Accordingly,
three boys schools and three girls schools were randomly selected from five boys and five girls schools in Siala. The sample was selected with an underlying assumption: other things being equal, the larger the sample, the greater the precision and the accuracy of the data it provides (Mouly, 1964).

For choosing the sample, three stage random sampling was employed. Random samples may be defined as those drawn in such a way that there is no reason to believe that bias will result, and that every case in the population has an equal chance of being selected (Rummel, 1959). At the first stage of sampling, three boys schools and three girls schools were randomly selected out of five boys schools and five girls schools. At the second stage, only one intact section of grade VI students from each of the chosen schools was randomly selected. Finally, these intact sections of boys and girls schools were further randomly divided into two equal parts for administering two experimental treatments. Thus two experimental conditions - administration of the small step programme and the large step programme - were created in each selected intact section. For random sampling at each stage, lottery method was followed. For this purpose a list was made of all the cases in the population and numbers were assigned to each case consecutively. The number of
each case was then written on identical slips of paper which were placed in a receptacle and mixed thoroughly. Then, the number of slips required were drawn from the receptacle. Though errors in the sampling - random or systematic cannot be completely eliminated, every possible effort was made to reduce them by increasing the size of the sample and also by randomising it.

Garret (1971), contends that if we draw samples at random from the population, we know at least that (a) there will be no consistent biases; (b) on the average these samples will be representative; (c) the degree of discrepancy likely to occur in any given sample can be determined by probability methods. Again, random selection is appropriate for data analysis which includes the use of inferential statistics (Fox, 1959).

Three stage random selection procedure adopted in this study resulted in four experimental groups of 75 students each with the following treatments:

Group 1 : Small step programme administered to boys
Group 2 : Small step programme administered to girls
Group 3 : Large step programme administered to boys
Group 4 : Large step programme administered to girls

A characteristic feature of each group was that the average age of the each group was about
11.2 years. All the four groups were found to be homogeneous in this regard.

The structure of the sample in respect of the schools randomly selected, for the experiment, is provided in Table 39.

**TABLE 39**

**STRUCTURE OF THE SAMPLE IN RESPECT OF THE CLASS, AVERAGE AGE, AND SCHOOLS SELECTED FOR THE EXPERIMENT**

<table>
<thead>
<tr>
<th>S.No.</th>
<th>School</th>
<th>No. of students</th>
<th>Average age in years</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Arya Girls High School</td>
<td>40</td>
<td>11.2</td>
</tr>
<tr>
<td>2.</td>
<td>Govt. Girls High School (Lakar Basar)</td>
<td>53</td>
<td>11.1</td>
</tr>
<tr>
<td>3.</td>
<td>Daya Nand Girls High School</td>
<td>52</td>
<td>11.2</td>
</tr>
<tr>
<td>4.</td>
<td>D.A.V. Boys High School</td>
<td>53</td>
<td>11.2</td>
</tr>
<tr>
<td>5.</td>
<td>S.D. Boys High School</td>
<td>53</td>
<td>11.5</td>
</tr>
<tr>
<td>6.</td>
<td>Govt. Boys High School</td>
<td>42</td>
<td>11.0</td>
</tr>
</tbody>
</table>

Total : 300 (150 boys, 150 girls)

It may be noted from Table 39 that the schools selected were exclusively for boys and girls. The total number of subjects were 300 (150 boys and 150 girls).

**EXPERIMENTATION**

As explained earlier, the present experiment based on a 2x2x3 factorial design was conducted on a sample of 300 students, both boys and girls equal in number,
drawn from intact sections of the sixth grade. Again, each selected intact section was divided into two halves for creating two experimental conditions - Administration of the small step and the large step programmes - within each section. The girls and the boys students were then pooled together separately to constitute four experimental groups of 75 students each. Finally, these groups were given four treatments: Small step boys and small step girls; large step boys and large step girls.

The layout of the experiment including the composition of the subjects in each group, is schematically explained in the following diagram:

Institutions

(Three boys and three girls schools)

Sample

(300 students from six intact section)

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Small step boys</th>
<th>Small Step girls</th>
<th>Large step boys</th>
<th>Large step girls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental groups</td>
<td>Group-I</td>
<td>Group II</td>
<td>Group III</td>
<td>Group IV</td>
</tr>
<tr>
<td>Group Size</td>
<td>75</td>
<td>75</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>Group Composition</td>
<td>( \left( \frac{A}{2} + \frac{B}{2} + \frac{C}{2} \right) )</td>
<td>( \left( \frac{X}{2} + \frac{Y}{2} + \frac{Z}{2} \right) )</td>
<td>( \left( \frac{A}{2} + \frac{B}{2} + \frac{C}{2} \right) )</td>
<td>( \left( \frac{X}{2} + \frac{Y}{2} + \frac{Z}{2} \right) )</td>
</tr>
</tbody>
</table>
A, B, C denote boys' sections and X, Y, Z denote girls' sections.

Before conducting the experiment appropriate rapport was established with the subjects. They were also given to understand that the purpose of the study was to examine certain research issues pertaining to the process of learning and not an evaluation of their performance. However, they were urged to work meticulously so that useful information could be gathered for the study.

The students were briefly acquainted with the method of learning through the programmed material. They were informed that they were going to learn elementary algebraical concepts and processes through a new method. They were also told that the content on Algebra had been broken into small steps and that each step, called a didule, followed on logically from the preceding didule so that it was easy to understand the content. Since learning through programmed material was a novel experience for the subjects, they evinced a lot of interest in it and remained attentive through out the experiment.

It was decided to conduct the experiment in the month of March 1975 when the students are promoted to the next grade to ensure that the subjects of the study - the new students in the grade VI - did not have
any learning of algebraic concepts at all. The experiment was
arranged according to a definite schedule and was completed
in eighteen working days by holding only one session per day.

The schedule for experimentation
is given in the Appendix A.

All possible precautions were
taken to ensure that the extraneous factors did not affect
the result. An attempt was also made to control the intra
procedural factors which could add an element of bias and
thereby contaminate the treatment effects. The five sources
of bias mentioned by Fox (1963), as follows, were duly
considered in the present experiment:

- **The Experimenter or His Agent**: The attitude of
  the experimenter or his associates may affect the
treatment effects differently. They might also
  create 'Hawthorne effect'. This effect refers to
  performance increments prompted by mere inclusion
  of the workers (or teachers) in an experiment
  (Taylor, 1952). This source of bias was controlled
  by seeking cooperation of those teachers who were
  not aware of the concept of programmed learning but
  had enough training to conduct the experiment.

- **Measuring Devices Employed**: The new sets of
  measuring devices employed in the experiment could
  avoid the effect related with this source of bias.
- Leakage or Dilution of Independent Variable: It was controlled by arranging the experiment in four separate rooms so that the subjects might not show curiosity for others. The subjects were also given to read the programme in rather a formal situation and the texts were collected after a unit was completed.

- The Experimental Conditions: The experimental conditions were kept similar in all the four experimental groups and the investigator along with his colleagues made every possible effort to keep strict vigilence throughout the experiment.

- The Experimental Process: The bias resulting from the experimental process itself was controlled by keeping experimental conditions similar in all the four experimental groups.

- Internal Validity of the Experiment: A study has internal validity if the outcome of the study is a function of the programme or approach being tested rather than the result of other causes not systematically dealt with in the study (Tuckman, 1972).

The process of conducting an experiment - exercising some control over the environment - contributes to internal validity. For an experiment to have
internal validity the researcher must establish experimental controls that will enable him to conclude that differences occur as a result of experimental treatments. Tuckman (1972), has described eight classes of extraneous variables, identified by Campbell and Stanley, which can be a source of internal invalidity, if not controlled. Every possible effort was made to control extraneous variables applicable in this study. The eight classes of extraneous variables are outlined as under:

- **History**: In research, the term 'history' refers to events occurring in the environment at the same time that the experimental variable is being tested. Limitations on internal validity by virtue of history were dealt with by providing the same external or historical experiences to all the four experimental groups. Further, materials, conditions and procedures used within the experiment were almost identical for the four groups.

- **Maturation**: Maturation refers to the process of changes that take place within those persons who are participating in the experiment. This extraneous factor was automatically controlled since the experiment in a particular school lasted only for three days.
- **Testing:** Testing applies to the effects of taking a pre-test on the subsequent post-test performance of individuals. In the present study, pre-test had no effect on the subsequent post-test performance since the subjects had no learning on algebraic concepts while taking the pre-test.

- **Instrumentation:** Instrumentation pertains to changes that occur in the measurement or observation procedures during an experiment. While the measuring instrument will not undergo a change during the course of an experiment, it is not unlikely that observers and scorers may change their manner of data collecting and recording as the experiment proceeds. Instrumentation poses threat only in the case of conducting interviews etc. It had absolutely no effect on the experiment conducted. However, there could be some danger to the internal validity, in case the teacher became aware of the purpose of the experiment and thereby consciously or unconsciously, attempted to increase the likelihood that the desired hypothesis could be supported. This risk was avoided by securing the services of the teachers who were not aware of the concept of programmed learning.
- **Selection**: The selection bias was efficiently controlled by the use of random assignment. The method of randomization was rigidly followed at the stage of selecting and assigning experimental treatments to different groups.

- **Statistical Regression**: Statistical regression refers to tendency on any post-test measurement for the higher scores to decrease towards the mean, and of the lower scores to increase towards the mean. But the problem of statistical regression occurs only when groups are chosen on the basis of extreme scores on a particular variable. In the present study the problem of statistical regression was not encountered since intact sections of grade VI were taken up for experimentation and similar experimental conditions were created within those sections as far as possible.

- **Experimental Mortality**: Experimental mortality was almost nil since the experiment was conducted for a short duration of three days in a particular school. However, to avoid any problem that could crop up because of experimental mortality, reasonably large groups were taken up for experimentation and their representativeness was assured by randomization.
- Stability: Bias due to stability implies a tendency for a finding to be unreliable, i.e. to occur once but not thereafter. This difficulty was met by examining the data through the use of 'F' and 't' tests which are reliable.

INTERACTIVE COMBINATION OF FACTORS

It is probable for the factors that affect validity to occur in combination. For example, Tuckman (1973), points out that a source of invalidity might be a selection - maturation interaction. In the present study, however, this problem did not arise since the experiment in a school was of very short duration and the age of almost all the subjects was eleven plus.

Thus the errors caused by sampling, experimental conditions etc., were tried to be minimised in every possible way.

EXPERIMENTAL PROCEDURE

Before exposing the subjects to the programmed material, the achievement test as pre-test was administered. The purpose of giving the pre-test was to assess the subjects' initial knowledge, if any, in Algebra. After this, the class was divided into two groups in accordance with the previously allotted identification number of each student. The two groups were then seated in different rooms. This was followed by
administration of the programme. The subjects were asked to read the instructions carefully given in the text before going through the programmed material. Each subject was allowed to proceed at his own pace. Average time taken by the students to complete each unit of the programme was recorded for various programme sets.

The details of the average time taken by the subjects for each unit are available in Table 40.

**Table 40**

**TOTAL AVERAGE TIME TAKEN TO COMPLETE THE PROGRAMME IN RESPECT OF SMALL STEP SIZE AND LARGE STEP SIZE FORMATS**

<table>
<thead>
<tr>
<th>Unit</th>
<th>Small Step Programme</th>
<th></th>
<th>Large Step Programme</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of frames</td>
<td>Average Time Taken</td>
<td>No. of frames</td>
<td>Average Time Taken</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hours Minutes</td>
<td></td>
<td>Hours Minutes</td>
</tr>
<tr>
<td>I (Knowledge)</td>
<td>467</td>
<td>4 - 34</td>
<td>399</td>
<td>3 - 48</td>
</tr>
<tr>
<td>II (Comprehension)</td>
<td>194</td>
<td>1 - 57</td>
<td>143</td>
<td>1 - 39</td>
</tr>
<tr>
<td>III (Application)</td>
<td>121</td>
<td>1 - 30</td>
<td>97</td>
<td>1 - 22</td>
</tr>
<tr>
<td>Total</td>
<td>792</td>
<td>3 - 01</td>
<td>593</td>
<td>6 - 49</td>
</tr>
</tbody>
</table>

The Table 40 indicates that average time taken by the small step format of the programme was eight hours and one minute and that for the large step format it was six hours and forty nine minutes.
The whole programme in each school was completed in three days. Only one unit of the programme was covered in a day. At the completion of each unit of the programme the relevant part of the achievement test was administered.

The test scripts were scored by the investigator for the test as a whole as also for each of the three taxonomic categories separately. The data was collected and organized for statistical analyses.

The various statistical techniques employed to interpret the data obtained as a result of treatments given to experimental groups are provided in the following pages.

**ANALYSIS OF VARIANCE**

The analysis of variance is a method for dividing the variation observed in experimental data into different parts, each part assignable to a known source, cause, or factor. We may assess the relative magnitude of variation resulting from different sources and ascertain whether a particular part of the variation is greater than expectation under the null hypothesis (Ferguson, 1971). It is mostly used for the important and oft-encountered problem of determining the significance of the difference among several means. It is a composite test that gives an over-all idea about the significance of difference
between means. The main characteristic of this technique is that variances can be simultaneously analysed into two components: the mean of the variances within the group, and the variance of the groups. Further, analysis of variance can also be applied to study the interaction effect.

The mixed factorial design employed in the present factorial experiment is as suggested by Lindquist (1956), and it satisfies the assumptions with certain limits of tolerance for applying analysis of variance.

In the analysis of data, the total sum of squares was broken up into between subject and within subject components. A, B and A x B interactions were 'between' components while C and A x C, B x C and AxBxC interactions were 'within' components. The main effects of A and B and the AxB interaction were tested against Mse error (b), and, main effects of C and A x C, B x C and AxBxC interactions were tested against Mse error (w). The analysis of various sum of squares has been given in Table 41.
### Table 41

**Analysis of 2x2x3 'Mixed' Factorial Design**

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Sum of Squares</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (step-size)</td>
<td>a-1</td>
<td>$SS_A$</td>
</tr>
<tr>
<td>B (Sex)</td>
<td>b-1</td>
<td>$SS_B$</td>
</tr>
<tr>
<td>AxB</td>
<td>(a-1)(b-1)</td>
<td>$SS_{AB} = SS_{AB} - SS_A - SS_B$</td>
</tr>
<tr>
<td>Error (c)</td>
<td>ab(n-1)</td>
<td>$SS_{error (c)} = SS_{Res (c)}$</td>
</tr>
<tr>
<td>C (Taxonomic Category)</td>
<td>(c-1)</td>
<td>$SS_C$</td>
</tr>
<tr>
<td>AxC</td>
<td>(a-1)(c-1)</td>
<td>$SS_{AC} = SS_{AC} - SS_A - SS_C$</td>
</tr>
<tr>
<td>BxM</td>
<td>(b-1)(c-1)</td>
<td>$SS_{BC} = SS_{BC} - SS_B - SS_C$</td>
</tr>
<tr>
<td>AxBxC</td>
<td>(a-1)(b-1)(c-1)</td>
<td>$SS_{ABC} = SS_{ABC} - SS_{A} - SS_{B} - SS_{C}$</td>
</tr>
<tr>
<td>Error (W)</td>
<td>ab(c-1)(n-1)</td>
<td>$SS_{error (W)} = SS_{Res (W)}$</td>
</tr>
<tr>
<td>Within Subjects</td>
<td>abn(c-1)</td>
<td>$SS_{WS} = SS_T - SS_g$</td>
</tr>
<tr>
<td>Total</td>
<td>abcn-1</td>
<td>$SS_T$</td>
</tr>
</tbody>
</table>

In the table small $a$, $b$ and $c$ represent the levels of factors A, B and C respectively. Small 'n' represents the number of subjects in each treatment combination and bar (·) represents the cell sum of squares.
Analysis of variance gives global picture about the nature of variance. A significant $F$ indicates that there are non-chance variations among means somewhere in the list of sets. The $F$ ratio cannot point out which one or how many means are significantly different. For this purpose 't' test was employed.

**LEVELS OF SIGNIFICANCE**

The customary level of significance, alpha, was adopted at .05 or less. Here the chances are 5 in 100, or less, that the difference between means could result when the treatment applied was having no effect. However by holding alpha, the probability of a type I error constant, the power of the test of significance was increased by increasing the numbers of observations to 900.

**ANALYSIS OF COVARIANCE**

The covariance analysis can help effect adjustments in the final or terminal scores which will allow for differences in some initial variable. In the planning for analysis of the obtained data it was stipulated to apply analysis of covariance but was later given up as a futile attempt since in the preliminary analysis of $X$ and $Y$ scores it was found that $F$ test as applied to intial ($X$) scores fell far short of significance at the .05 level of confidence. It therefore signified that $X$ means did not differ significantly and also that the random assignment
of subjects to the three groups was quite successful. Further, it was also revealed that the experimental groups had little learning in Algebra which could affect their terminal scores (The X means for each group were seven less than 2.00). Furthermore the correlation between X and Y scores was very negligible.