Chapter IV

Experimental design and execution

4.0 Introduction:

Research design is strategy on paper like an architect’s plan. Certain fundamental steps of research design must be given importance when proposed to be used. The operation of the design, that is planning must be carried out with patience and accuracy. The purpose of research design is to impose controlled restrictions on observations of natural phenomena. It helps the investigator, what to do during the study.

The quality of research depends upon the quality of its design. If the research design is faulty then the final result would be faulty. Therefore, a proper design is needed for valid analysis.

This chapter deals with the selection of proper research design for the study. For validation of study, the experimental design was used. Research tools and sampling procedure are described.

4.1 Basis elements of research method

The basic elements of research method are variables, hypotheses, research tools, and sample selection. Each one of the four elements is described in detail below.

4.1.1 Variables therein:

There are several special programmes available for developing achievement of students toward mathematics. There were also programmes like CAT, SMSG, SMP, and PSSC for developing improved instruction materials. But all of them are special programmes can not be used in an ordinary classroom without distributing its activities. A programme that could be used without causing any inconvenience to the pupils has to be developed. This laboratory teaching programmes provides such type of facility.
LTP is based on two sound psychological principles namely, “proceed from concrete to abstract” and “learn by doing.” It produces quality improvement in achievement of student through using certain models and activities. Since one of the objectives of the study is to study its effect on pupils achievement towards mathematics. Thus, treatment was chosen as an independent variable. Treatment, Sex, SES, and I.Q were considered as independent variables. Achievement was chosen as dependent variable. Detail about variables is given in chapter I. (1.6).

4.1.2. Hypotheses: The hypotheses formulated for this study as mentioned chapter I (1.8).

4.1.3 Tools used:

The selection of an appropriate tool for measuring the value of variables is one of the most critical components of the research process. The following tools were used in this study.

(i) Laboratory teaching programme developed by the investigator.

(ii) Achievement test in mathematics developed by the investigator.

(iii) I.Q. test developed by Dr.K.G.Desai.

(iv) SES test developed by Dr.H.N.Tapodhan.

(i) Laboratory teaching programme:

This programme is developed by the investigator. It has ten programmes covering the at most all content of mathematics of standard VIII of Gujarat state. This lesson programme was described in detail in chapter III.

The aim of this programme is to be improved achievement of students toward mathematics. Each programme is developed in such a way that the subject becomes functional and meaningful to learner. Each programme supplements and enriches the usual classroom instruction. All the LTP are appended in Appendix 1.

(ii) Achievement test in mathematics:

This achievement test is developed by the investigator. It has three questions. Question I, consist of objective type questions. In this question there are three sub questions. 1(A), 1(B) and 1(C) consist of fill in blank, true-false and multiple optional type questions respectively. Question 2 consist short type questions. Question 3 consist long type questions. The content of this achievement test covers the all topics of LTP. With the help of this tool investigator wanted to measured the achievement scores in mathematics. The reliability of this test has been established by test-retest method. The
test-retest interval was about two weeks. The test retest reliability was found 0.85. This indicates that the test is reliable. It was shown in Appendix 2.

(iii) I.Q. test:

Keeping in view the criteria for selection, the I.Q. test for std. VIII, IX, X, XI, XII and college developed and standardized by Dr.K.G.Desai was selected for finding I.Q. of the pupils for present study. This I.Q. test was developed in 1992. It contained four verbal and four non verbal sub tests. This test could be given to 8th, 9th, 10th, 11th, and 12th standard student moreover it could be given college training institute as well as higher degree students. In this test answer sheet and questionnaire are separated. This is omnibus test. Eight illustrations are given for each of eight sub tests. Organizer of the test has to explain these illustrations before the exam start. Students have to give answer of eighty questions in forty minutes as many as possible. This test is easy to conduct, normal school teacher also able to conduct this test. All instruction which are printed on the answer sheet must be follow strictly, casualness in regarding to these instruction may be spoil the result. The norms of this test were fixed after conducting this test on large number of sample. This sample was consisting of 1437 boy and 1308 girls. Average score according to age is given in table. Maximum score can be possible is 80.

Reliability-validity of the I.Q test:

The reliability and validity of the tests has been established by various methods, which are:

1. Test-Retest method,
2. Split-Half method.
3. Co-relation between verbal and nonverbal score was calculated to check validity of this test. It was 0.78. & Mv = 21.10 & Mnv = 20.91 mean different is 0.2 which is not significant.

4. Co-relation between this test and Desai-Bhatt group I.Q. test score was calculated to check validity of this test. It was 0.78 which suggest simultaneous validity.

After administered the I.Q test all the answer sheets were scored with use of window stencils. Total raw scores were written in the space provided in the answer sheets. The test is appended in Appendix 4. Two groups were made on basis of I.Q. scores.

A score of 93 or less than 93 was taken as low I.Q. and a score 110 or greater than 110 was taken as high I.Q. of the students.
(iv) Social economical rating scale:

This is a very simple tool design by Dr. H.N. Tapodhan. It contains items like information of family, educational qualification of family members, monthly income of family members, vehicles, accommodation, and home appliance. The student is required to tick the appropriate box and in some blanks, the student has to write figures. A score of 13 or less than 13 was taken as low SES and a score 19 or greater than 19 was taken as high SES of the students.

4.1.4 Sample selection:

A major link in the chain of reasoning for inferential statistics is the sample. Samples are selected from a population, and measures computed from the samples (statistics) are used to make inference about the population measures (parametory). A sample should be too large. The real worth of a sample lies not in its size but in its accuracy and representativeness.

According to Johnson [14, P186]

“A representative sampling is defined as one, with which the measurements made on its units are equivalent to those which would be obtained by measuring all the elements of the population, except for the inaccuracy due to the limited size of sample.”

Travers [26, P205] defined sampling as:

“A representative sampling is one in which the characteristics of the sample are similar in important respects to characteristics of the population sampled.”

Hence, representative sampling should be carefully determined. There are different methods of sampling. According to Rumell [21, P 74-80], they are as follows:

(i) Random sampling (ii) Stratified sampling (iii) Area sampling (iv) Systematic sampling (v) Purposive sampling and (vi) Quota sampling

Garrett [12, P203] suggested the following method:

(i) Random sampling (ii) Stratified sampling (iii) Incidental sampling and (iv) Purposive sampling.

Now the investigator had to select such a sample, which would satisfy the following characteristics:

a) In general, I.Q. of the pupils should be distributed normally.

b) The school should be known to the investigator for easy approach and full cooperation of the pupils as well as the staff.
c) The school should have co-educational system.

d) The school should have at least four classes of std. VIII.

Looking to the above requirements, the investigator selected the purposive sampling technique for this study. In most general sense, it means selection according to some purposive principles.

Purposive sampling is a non-probability from of sampling. Under this method one can select the available sample. This method has to be followed when it is not possible to identity all the subjects of the universe or when it is not possible to disturb the subjects due to administrative reasons as in the case of a classroom experiment.

Garrett[12, P 207] defined purposive sampling as: “A sample may be expressly chosen because, in the light of available evidence, it mirrors some larger group with reference to a given characteristic.”

The school satisfying all the requisite conditions named Gurukrupa Vidhyalaya, Ahmedabad was selected for the present study. There were 220 students in standard VII.

4.1.5 Formation of equal groups:

On the basis of I.Q. score two equal group formed from four sections of VII standard of selected school. These equal group made by making equal pair from I.Q. score. From these two groups one group was randomly selected as treatment group and other as control group. Each of these group divided in two classes. Total number of pupils was 220. Each class contains 55 students. No. of students, mean scores, S.D. of two formed groups A₁ & A₂ are shown in table 4.1.

<table>
<thead>
<tr>
<th>Group</th>
<th>Number of students</th>
<th>Mean of I.Q. score</th>
<th>S.D.</th>
<th>C.R.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A₁</td>
<td>110</td>
<td>101.45</td>
<td>9.9203</td>
<td>0.0271</td>
</tr>
<tr>
<td>A₂</td>
<td>110</td>
<td>101.49</td>
<td>9.9816</td>
<td></td>
</tr>
</tbody>
</table>

Here \( M₁ = 101.4545, \ M₂ = 101.4909, \ M_{D} = M₁ - M₂ \)

= 0.0364

From table 4.1 \( \sigma_{A₁} = 9.9203 \) \( N_{A₁} = 110 \) \( \sigma_{A₂} = 9.9816 \) \( N_{A₂} = 110 \)
\[ \sigma_D = \sqrt{\frac{\sigma_1^2}{N_1} + \frac{\sigma_2^2}{N_2}} \]

\[ \sigma_D = 1.3418 \]

\[ C.R = \frac{M_D}{\sigma_D} \]

\[ = 0.0271 \]

\[ df = N_1 + N_2 - 2 = 218 \]

Here, observed value of C.R. is 0.0271. It is very less than the table value 1.96 [12, P461]. Hence, it is not significant at both the levels.

Therefore, it is concluded that the two equal groups, A1 was selected as an experimental group (treatment group) and A2 s control group by random process. Now S.E.S. was administered to the two groups so that the sample could be further partitioned. The numbers of subjects in the sixteen cells are adjusted such that each cell had seven subjects. Then the control group and experimental (treatment group) each has fifty six students. Out of them, twenty eight are boys and twenty eight are girls.

The choice of the institution and then the selection of the pupils made the sample purposive. Since the school chosen was normal one, it can be assumed to be representative of the population.

**4.2 Statistical Techniques: Experimental Design:**

For testing the hypotheses an experimental design is needed. In the experimental design the investigator control one or more independent variables and observes the dependent variable for corresponding changes.

The designs are classified into two groups or categories:

1. Inadequate designs or quasi experimental designs, and
2. General experimental designs

**4.2.1 Quasi – experimental designs:**

The one group design come under the first category. It is also known as one-short case study. Case studies fall under this group and enhance the name. In this design a group is exposed to some treatment and after a period the effect is measured. For example if a school wants to introduce a new curriculum and study its effects. After a year the
student achievement is studied and found to be same or better. Symbolically it is denoted by \( \text{X} \) \( \text{Y} \). Here the dependent variable \( Y \) is studied while the independent variable \( X \) is assumed or imagined sometimes conclusions could be misleading.

Another form of one-group design is the pre test-post test type. This is an improvement over the previous method. The important characteristic of this design is that a group is compared with itself. This is theoretically sound since all the independent variables associated with the subjects characteristics are controlled. The group is measured on the dependent variable \( Y \) before the experiment. It is called pre test. After the experimental manipulation again \( Y \) is measured. The differences in scores or \( Y_a - Y_b \) are studied. Symbolically it can be shown as \( Y_b \uparrow \text{X} \downarrow Y_a \).

Though this appears to be sound it is not that simple. The difference might have been caused by variables like history or maturity.

4.2.2 General Designs:

(I) The experimental-control group design is one of the best design for many experimental purposes in education and psychology. The paradigm is

\[
\begin{array}{c}
\text{R} \quad \text{X} \quad \text{Y} \\
\sim \quad \text{Y} \\
\text{Y} \\
\text{Y} \\
\text{(experimental)} \\
\text{(control)}
\end{array}
\]

The \( R \) placed before the design shows that subjects are to be randomly assigned to the experimental group and control group. There are two merits of the method:

1. The presence of a control group gives the comparability required by science, and
2. Randomization provides assurance that the two groups are approximately equal on variables that may be related to the dependent variables.

(II) The two group-method subjects design is another. Here instead of randomization the subjects are matched on one or more attributes. Symbolically it is represented as:

\[
\begin{array}{c}
\text{Mr} \quad \text{X} \quad \text{Y} \\
\sim \quad \text{Y} \\
\text{Y} \\
\text{Y} \\
\text{(experimental)} \\
\text{(control)}
\end{array}
\]

The suffix \( r \) shows that after matching the member of each pair must be assigned to the two groups randomly. This can be done by using random numbers. Odd numbered subjects are counted into one group and the even numbered subjects are counted into another group.

(III) Three group before-after.
Its paradigm is

\[ R \begin{bmatrix} y_b & x & y_a \\ y_b & -x & y_a \\ x & y_a \end{bmatrix} \frac{(experimental)}{(control-1)} \frac{(control)}{(control-2)} \]

This is an improvement over the previous design. It avoids the possible interactive effects of the pre-test. This is done by the second control group. If the treatment is effective than the means of experimental group and control group -2 will be significantly higher than the mean of control group-1.

(IV) Four-group, before-after (Solomon). This design was proposed by Solomon. It paradigm is

\[ R \begin{bmatrix} y_b & x & x_a \\ y_b & -x & y_a \\ -x & y_a \end{bmatrix} \frac{(experimental)}{(control-1)} \frac{(control)}{(control-2)} \frac{(control-3)}{(control-4)} \]

This design has powerful controls. The salient features of the previous designs are included in this design. It is widely used by social scientist.

4.2.3 Choice of the Design:

In deciding an approach, the investigator has to take into consideration several factor like available setting, nature of objectives and time.

Two separate and independent dimensions can help the investigator in the choice of approach. Fox[10, P 46] had suggested the following table.

**TABLE 4.2**

**INTERACTION OF TIME AND INTENT DIMENSIONS**

<table>
<thead>
<tr>
<th>Dimension-2</th>
<th>Dimension-1</th>
<th>(Time which interest lies)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Past</td>
<td>Present</td>
</tr>
<tr>
<td>Intent of Research</td>
<td>Historical</td>
<td>Survey</td>
</tr>
<tr>
<td>Description</td>
<td>Simple historical</td>
<td>Simple Survey</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comparison</td>
<td>Parallel historical</td>
<td>Multiple group Survey</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evaluation</td>
<td>Historical and criterion measure</td>
<td>Single group or multiple group survey criterion measure</td>
</tr>
</tbody>
</table>
The use of the above table in the present case leads to the choice of multiple independent variables each of two levels a factorial design is called for.

4.2.4 ANOVA: Factorial Design:

According to Kerlinger [14, P351].

“Factorial Design is the structure of research in which two or more independent variables are just apposed in order to study their independent and interactive effects on a dependent variable.”

In the present experiment the independent variables are treatment (A), sex (B), I.Q. (C), SES (D). Each is at 2 levels. It is a 2^4 factorial experiment.

Factorial analysis of variance has several advantages. It enables the researcher to manipulate and control two or more variables. Secondly, variables like sex; SES etc. that cannot be manipulated can also be controlled. Factorial analysis is more precise than the one-way analysis, it is the third advantage. Finally the interactive effects could be studied. This is important from a scientific point of view.

4.2.5 Statistical technique in ANOVA:

Here Treatment (A), Sex (B), I.Q. (C), and SES (D) are the independent variables each at two levels. In all there are sixteen blocks. They are shown in table 4.4

The F-test is based on the following assumptions:

1) An equal unit scale is assumed for the measurement of the dependent variable.
2) Homogeneity of variance.

The ANOVA summary shown in table 4.3 helps in testing whether the group means differ or not.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Sum of squares</th>
<th>df</th>
<th>Mean SS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between the groups</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within the groups</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The 0.05 & 0.01 confidence levels were taken to test for significance. $2^4$ factorial design for data analysis shown in table 4.4.

**Table: 4.4**

<table>
<thead>
<tr>
<th></th>
<th>$A_1$</th>
<th></th>
<th>$A_2$</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$B_1$</td>
<td>$C_1$</td>
<td>$C_2$</td>
<td>$C_1$</td>
<td>$C_2$</td>
</tr>
<tr>
<td></td>
<td>$D_1$</td>
<td>$D_2$</td>
<td>$D_1$</td>
<td>$D_2$</td>
</tr>
<tr>
<td>$B_2$</td>
<td>$C_1$</td>
<td>$C_2$</td>
<td>$C_1$</td>
<td>$C_2$</td>
</tr>
<tr>
<td></td>
<td>$D_1$</td>
<td>$D_2$</td>
<td>$D_1$</td>
<td>$D_2$</td>
</tr>
</tbody>
</table>

To test the mean effects and interaction effects complete ANOVA is used with the help of orthogonal system. The full form is shown in table 4.5.

The values of F are obtained by dividing each of the mean sums of square (MSS) by error variance, i.e. within groups mean square. The level of significance at 0.05 and 0.01 levels of confidence has been accepted to study the main effect and interaction effect on the dependent variable. Thus, the hypothesis could be tested for acceptance or rejection.

**Table 4.5**

*Summary of variance four ways ANOVA*

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>SS</th>
<th>Df</th>
<th>MSS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$A \times B$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$A \times C$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$A \times D$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$B \times C$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$B \times D$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$C \times D$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$A \times B \times C$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$A \times B \times D$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$A \times C \times D$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$B \times C \times D$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$A \times B \times C \times D$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Error</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4.3 Execution of the experiment:

There were two groups under experiment. One was the experiment group and other was the control group. Treatment was given to the experimental group. Control group was taught by traditional method. Both groups were treated in the usual manner. They were asked to be punctual, regular and neat in their work. Whenever there was an execution of the programme students were informed well before. Regular and continuous effort will yield good results and better learning takes place.

4.3.1 Instructions to experimental group:

Whatever necessary treatment is required to the experimental group was provided by the investigator himself. In the beginning the investigator provided the instructions given in programme booklet, appendix 1.

4.3.2 Time schedule for the execution of programme:

The following time schedule was used applying the treatment. Each LTP idea programme required different time as per content of the programme:

Table 4.6

<table>
<thead>
<tr>
<th>Month</th>
<th>Name of programme</th>
</tr>
</thead>
<tbody>
<tr>
<td>June</td>
<td>Set theory</td>
</tr>
<tr>
<td>July</td>
<td>Expansion</td>
</tr>
<tr>
<td>September</td>
<td>Structure of geometry, point, line and distance</td>
</tr>
<tr>
<td>October</td>
<td>Statistics</td>
</tr>
<tr>
<td>November</td>
<td>Factorization</td>
</tr>
<tr>
<td>December</td>
<td>Line segment, ray, plane and angle</td>
</tr>
<tr>
<td>January</td>
<td>Parallel line, Circle</td>
</tr>
<tr>
<td>February</td>
<td>Construction, Area and volume</td>
</tr>
<tr>
<td>March</td>
<td>Examination</td>
</tr>
</tbody>
</table>

After completion of the programme the achievement test in mathematics was administered to both groups under experiment at the same time.

4.3.3 Execution of LTP:

The teacher had chosen the strategies selected by him for each lesson idea programme and through the content tried to develop the appropriate achievement of student in mathematics.
Each LTP contains reading material, worksheet & KIT. Investigator prepared and kept worksheet & kit ready well in advance. It was arranged at proper place in the classroom before a work started.

Every student was provided one file & booklet for each programme and one kit was provided between two students.

4.3.4 Observations:

During the implementation of LTP investigator recorded some observations at the time of the experiment. The following description contains them in all detail.

1. **Set theory**

The first programme was related to the concept of set theory. In this programme first of all student had to read the given reading material. They read that paper quietly; some students had doubt about some concept due to new chapter. So investigators explained the doubts and solve their queries.

This chapter is introductory chapter for these students. So the programme was started with the activity of analysis of cards of animals like birds, wild animals and reptiles. They performed this activity easily. Students enjoyed this activity. Through this activity they understood the concept of analysis and how to make different sets.

Then in the next experiment, they took kit S₂ in this kit they selected cards of number 1 to 20 and prepared some sets which satisfy the given property. They prepared six different sets. With the help of this information they filled blanks given in the worksheet. The last experiment was related to Venn diagram. First of all students read given data like universal set & given set A, B, C, D etc. From this information they prepared Venn diagram on white paper with the help transparent cards. They enjoyed these activities. Then they filled the given blank.

In this programme students learned concepts of set, subset, universal set, empty set, operations of sets like union of sets, intersection of sets and compliment of set. Also they learned concept of belongs to and does not belong to.

2. **Expansion**

The third programme was about the expansion of equation. Students were familiar with some of expansions in their previous study. But they did not know how to expand that by using model.

In this programme there were six expansions. In the first experiment students took kit E₁ from this kit they picked up some squares and rectangles from the colour card.
Students were asked to make one integrated square. Then they wrote the length, breath and area of the integrated square in the given table. After this activity students wrote the measurement of each squares & rectangles given in that kit, in the work sheet. Then they compared the area of integrated square with the small squares & rectangles from this activity they found the expansion of \((a + b)^2 = a^2 + 2ab + b^2\). They were excited with the result. They enjoyed this activity.

Similarly they found the expansions of \((a - b)^2\), \((a + b)(a - b)\), \((a + b + c)^2\), \((a + b)^2 - (a - b)^2\), \((x + a)(x + b)\). In this programme students used their creativity to make integrated square. From this whole experiment they learned algebra with the help of geometry. They enjoyed the integration of geometry and algebra. This was new experience for the students.

3. **Point, line and distance**

This programme was concerned with the concept of point, line & distance. In this programme they read reading material quietly.

In the first experiment they asked to draw as many as possible lines passing though given point. They concluded the result that infinite lines pass though one point. In the postulate related to lines for this the used scale and pencil. Also they derived conclusions related to collinear and non collinear points. Also they develop concept of belongs to and does not belong to, intersection and subset.

In the second experiment, students measured distance between two points with the help of scale. They fill the blank with >, <, =, ≠. In the third experiment students used number line strip and found the number related to given point with respect to given point O. In the fourth experiment students calculated the distance between two points without the help of scale. In the fifth experiment students found appropriate number related to point which was given at some fixed distance from the given point with the use of number line strip. In the sixth experiment student solved the equation \(|x - 2| = 5\) by experiment.

In the last experiment students measured distance between two cities in map of Gujarat state with the help of scale. They found approximate distance between two cities in kilometer.

4. **Analysis of data**

The second programme was associated with the concept of analysis of information (statistics). For this programme students were asked to come with their last exam marks
and their height. Height was measured one day before implementation of the programme. So students had this information.

First of all investigator had divided the class into two groups. Each group had given their data which was written on the black board by investigator. Students wrote these data for particular group.

Then in the next step students read the given reading material. After silent reading, students asked to perform the experiment. In this experiment students had filled given blank and prepared frequency distribution table. Then they found lower limit point & upper limit point. & mean for their marks. In the next experiment they did the same for the data related to height.

At last students calculated the average marks and average height for the whole class. In this programme students learned the concept of continuous variable, discrete variable, class interval, limits of interval, limit points of interval, mean and group mean. Also student were eager to know which group was better than other group for their marks.

5. Factorization

This programme were about factorization. Students were already taught some concepts to factorize given polynomial with the help of number & common factors. But this was totally new experimental method of findings factors of the given polynomial.

First of all students had read the reading material then investigator explained the method with two illustrations. Then they had started their experiment.

In the first experiment students were asked to find factor of $x^2 + 3x + 2$. So they took the kit $F_i$ and from these kit they took a square whose area equal to $x^2$, three rectangles whose area equal to $x$ and two squares whose area equal to 1. From these pieces they prepared one integrated rectangle. Then, they compared these two calculated area. Surprising they got factor of $x^2 + 3x + 2 = (x + 2) (x + 1)$. Similarly they found factors of $x^2 + 7x + 10$, $2x^2 + 5xy + 2y^2$, $x^2 + 2x – 8$, $2x^2 + xy – y^2$.

In this programme students learned how to find factor using squares and rectangles. They told that this method is very stress less and enjoyable.

6. Line segment, ray, plane and angle

This programme was related to the concept of line segment ray, plane and angle. In these programme students read given reading material for line segment then they performed experiment related a line segment. Then after, they read about ray and so on. For the experiments of plane students used cuboids. For angle’s experiment they used protractor.
In this experiment students did some activities. They drew figures, measured line segments and angles and filled up the given blanks. Students derived conclusion with the help of observations, measurements and their logics. Some of these activities developed their visualization and measurement skills.

In this experiment some students face difficulty to use protractor. So their conclusion was wrong therefore meanwhile the programme investigator showed them how to use protractor in a correct manner. Then they derived exact conclusion.

7. **Parallel lines**

The seventh programme was about the parallel lines. In this programme first they read the given reading material quietly. Then they performed the experiments one by one. Students used observation and measurement skills to derive results related to parallel lines and its transversal.

In this programme students learned properties of parallel lines with the help of protractor and scale. They learned construction to divide the line segment into equal parts. End of the programme students were able to find unknown angles and measurement of line segment without using a scale and protractor. But they found this with the help of properties of parallel lines which they derived in previous experiment.

8. **Construction**

This programme was related to construction of angles. In the first experiment, students constructed congruent angles with the help of a compass and scale. In the next experiment, they bisected given angle with the help of compass and scale. Then they constructed angles of $60^0$, $120^0$, $90^0$ angles also they performed experiment to construct perpendicular to line from a point outside of the line. At last they constructed perpendicular bisector to the line segment.

9. **Circle**

This experiment was associated with the concept to circle. First of all students read given reading material. In the first experiment students found the relation and properties of chord, diameter and radius with the help of scale. In the next experiment they measured three different figures and concluded that perpendicular from centre to chord bisect the chord. Similarly they derived others results related to circles in next nine experiments. Up to tenth experiment students used a scale and protractor to conclude results. But in last experiment they found unknown angels without using scale and protractor.
10. Surface area and volume

This experiment was related to the concept of area and volume. This programme was divided into two parts and the class was divided into three equal groups. These three groups performed experiment in rotation. First turn was about first three experiments. These experiments were related to basic concepts of volume. Students found volume of non regular solid by using measuring cylinder and water. In the next experiment students put round pieces of paper one by one and made cylinder and derived formula for volume of cylinder. Similarly they found volume of cuboids. In the next turn students found surface area and volume of cylinder with the help of paper, string and formula which they had already derived. Then they did experiment to find volume of cone with the help of three cones and cylinder, water jug, marked cylinder. Then they found relation between height, radius and slant height of cone with the help of half cone. Also they found surface area and volume of the given cone with the help of formula.

Students enjoyed this programme. They were very happy to do the experiment. They told that they had never done this type of experiment in mathematics.

4.4 Summary

This experiment was conducted with a two group design. There were four independent variables each of two levels. $2^4$ factorial design was use. The time schedule and execution of the programme were described in this chapter. The experience of the investigator, the reactions of the pupils and the teacher strategies worked were described in detail for each laboratory teaching programme. The whole programme was completed smoothly and the pupils expressed satisfaction of the teaching.