CHAPTER IV

METHODOLOGY

- **Method adopted for the study**
- **Design selected**
- **Variables of the study**
- **Sample selected for the study**
- **Tools and materials used for the study**
- **Description of the tools and materials used**

METHODOLOGY

By methods we mean that range of approaches used in educational research to gather data which are to be used as a basis for explanation and prediction. If methods refer to techniques and procedures used in the process of data gathering, the aim of methodology then is to describe approaches to kinds and paradigms of research (Kaplan, 1973). He suggests that the aim of methodology is to help us to understand, in the broadest possible terms, not the products of scientific Inquiry, but the process itself.

Research methods are of utmost importance in a research process. They describe the various steps of the plan of attack to be adopted in solving a research problem, such as, the manner in which the problems are formulated, the definition of terms, the choice of subjects for investigation, the validation of data gathering tools, the collection, analysis and interpretation of data and the processes of inferences and generalizations (Koul, 1984).

Any research for its success depends on the stability of the method and the training that the researcher receives. The details regarding the method adopted, design selected, variables and tools used, sample selected, procedure adopted in the administration of tools and statistical techniques used for the analysis of data are given in this chapter. It has been described under the following major heads:

I. Method adopted.

II. Design selected.

III. Variables of the study.

IV. Sample selected for the study.

V. Tools & Materials used for the study.

VI. Description of the tools & materials.

VII. Statistical Techniques adopted for the Study.

4.1. METHOD ADOPTED FOR THE STUDY

The study was intended to find out the "Effectiveness of Polya's Approach on Problem Solving and Problem Creating Ability in Mathematics of Secondary School Students".

Here the Investigator selected survey cum-experimental method to conduct the study. A Questionnaire was prepared and distributed to 200 secondary school students to collect data regarding their difficulty in solving problems and to find out the need of using Polya's approach in teaching problems. An evaluation proforma based on Polya's approach were given to secondary school teachers to find out their perception regarding Polya's approach with reference to Geometry , Algebra and Arithmetic. Experimental research is the name given to the type of educational research in which the Investigator controls the educative factors to which a child or group of children is subjected during the period of inquiry and observes the resulting achievement. The essential feature of experimental research is that the Investigator deliberately controls certain conditions and manipulates certain other conditions which determine the events, in which they are interested, introduce an intervention and measure the difference that it makes.

4.2. DESIGN SELECTED

The design selected for the present study was 'pre-test – post test non equivalent group design. An experimental design to the researcher is what a blue print is to an architect. It provides the researcher an opportunity for comparison

required by the hypotheses of the experiment and enables him to make a meaningful interpretation of the results of the study with the help of analysis of the data. The two groups involved in the study are compared in the following pattern.

4.3. VARIABLES OF THE STUDY

Variables are the conditions or characteristics that the experimenter manipulates, controls or observes (Best and Kahn, 2005). For an experimental study there are independent variables and dependent variables.

4.3.1. Independent variables

The variables which are manipulated by the experimenter or the variables which are suspected of being the cause in the experiment are called independent variables. In the present study, teaching method is the independent variable. Polya's approach and existing activity oriented method of instruction where the independent variables selected for the study.

4.3.2. Dependent variables

"The dependent variables are the conditions that appear, disappear or change as the Investigator introduces, changes or removes independent variables" (Best, 1995). The dependent variables of this study are the mathematical problem solving and mathematical problem creating ability of the students.

4.4. SAMPLE SELECTED FOR THE STUDY

A good sample is one that is representative of the population from which it was selected. By observing the characteristics of the sample, it is possible to make certain inferences and generalizations about the characteristics of the population from which it is drawn. A sample of 200 students were selected from Fathima Girl's High School, Fort Kochi for administering the questionnaire. As the sample

for the experimental part again, two hundred students were selected from two divisions of St. Mary's A.I.G.H.S Fort Kochi and two divisions of St. John De Britto Higher Secondary School Fort Kochi. Hundred students were taken as sample for the experimental group and the remaining hundred as control group. The experimental group was taught by Polya's approach and the control group by the prevailing activity oriented method.

4.5. TOOLS AND MATERIALS USED FOR THE STUDY

For the collection of data for the study, the Investigator herself prepared the following tools and materials:

1. Questionnaire to students
2. Polya's approach Evaluation Proforma to Teachers
3. Lesson transcripts based on Polya's Approach meant for the experimental group.
4. Lesson transcripts based on activity oriented method for the control group.
5. Mathematical Problem Solving Ability test.
6. Mathematical Problem Creating Ability test.

4.6. DESCRIPTION OF THE TOOLS AND MATERIALS USED

One of the most important aspects of teaching mathematical concepts and procedures is to provide students with an opportunity to develop a rich array of representations for each mathematical situation. The stronger the connections between the various representations, the stronger the problem solving performance and vice versa. The benefit of problem solving strategies lies in the ability of the problem solver to use them thoughtfully and intelligently as ways to better understand the problem situation and look for ways to bring their mathematical

knowledge to bear on the situation. Students will use strategies more successfully when they monitor their own problem solving process.

4.6.1 Questionnaire to Students

The questionnaire gives a vivid picture about the difficulties students face in mathematics with special reference to Geometry, algebra, and arithmetic . It presents the area of difficulty and the constraints students come across while solving problems in mathematics.

The difficulties are categorised into 4 heads such as difficulty in understanding the problem, difficulty in devising a plan, difficulty in carrying out the plan and the habit of looking back. Altogether there were 24 questions in the draft questionnaire. And out of this , 2 were general questions which do not come under these categories

Understanding the problem: This part intends to know how the students attack a particular problem. There were 4 questions under this section in the draft questionnaire.

Devising a plan: This part calls for responses to know whether the students device a plan in mind in advance for solving a problem. In the draft questionnaire there were 8 questions .

Carrying out the plan: Aims to know how the students proceed with the devised plan. Initially there were 6 questions in this part.

Looking Back: This part intends to call for opinion regarding the habit of checking the steps and cross checking the final results of the problem . This part had 4 questions in the draft questionnaire

Try Out: The prepared draft questionnaire with 24 items was administered to a sample of 50 students to know the technical difficulties if any and to know the clarity appropriateness and genuineness of the questions. After the administration the vague, unclear and abstract questions were removed. i.e. Two questions from the first part , two from the second part , 3 from the third part and 2 from the last pat . Thus 15 items were taken for the final questionnaire. Questionnaire is appended in Appendix No. I

4.6.2 Polya's Approach Evaluation Proforma to Teachers

After the preparation of the lesson transcripts based on Polya's approach a proforma for evaluating this material was prepared. And a survey was conducted among 100 secondary school teachers in order to evaluate the same. 100 teachers who are having long years of teaching experience and less years of teaching experience responded to this proforma by giving their perception regarding material.

The proforma drafted with 21 items giving due weightage to select 3 thrust areas such as Geometry, Algebra and Arithmetic. 7 Items each related to each subarea were prepared . It was discussed among experts in the field and finalized it with modifications by removing the ambiguities. .And the final tool

contained 15 items , 5 in each section. And the respondents were asked to give their perceptions regarding the statements.

The tool is administered to 100 secondary school mathematics teachers and they are classified into two groups according to their years of teaching experience 64 % of the respondents has more than 15 years of experience and 36% has less than 15 years of experience. Proforma is appended in the appendix as Appendix No. 2.

4.6.3 Lesson transcripts based on Polya's approach

Polya is considered to be the father of Problem Solving. Polya's prescription for solving problems consists of four steps that use the 3R's of Problem Solving, i.e., Request, Response, Result and Verification of Result. His technique is called *heuristics* i.e., serving to discover strategies that aid in solving problems. Heuristics provide a road map. They are blue prints that directs a path towards the solution and resolution of a problem situation. Unlike an algorithm they cannot guarantee success. However if our students are taught to follow these heuristics in every problem situation they face, then they will be in a good position to resolve successfully the problems they will face in the classroom and in life.

Teaching mathematics through problem solving provides a learning environment for students to explore problems on their own and to invent ways to solve the problems. Such activities allow them to facilitate connections of related ideas to consolidate their mathematical knowledge and to think creatively (Polya, 1973; Kalaman, 2004 and Rudnick, 1994). Polya's approach consists of certain pre-determined steps which are to be followed strictly by the teacher so as to attain

the desired results. The teacher must help the child to use the sub steps of Polya's approach until he reaches a solution.

Portions were taken from IX standard mathematics text book of state syllabus. One chapter each from geometry, algebra and arithmetic were selected for the study. Chapter on circles was taken from geometry, pairs of equations from algebra and irrational numbers from arithmetic.

The main reasons for selecting these units are:

- They contain many sub topics with number of concepts.
- They form basis for a sound mathematical understanding.
- They are widely related with almost all branches of mathematics.
- They mainly deal with logical reasoning and higher order thinking.

Lesson transcripts based on Polya's approach meant for the experimental group was prepared by selecting topics from three areas of mathematics. The three chapters were dealt in detail, using Polya's approach. Lesson plans were written for each topic using the steps of Polya's approach (Polya, 1973). The Lesson Transcripts were modified as per the perceptions of the teachers and as per the difficulties revealed by the students. The first step of Polya's approach is:

4.6.3.1. Understanding the problem (Recognizing what is asked for) - A problem is basically a conflicting situation in which a person experiences frustration in achieving a goal. The frustration may be a barrier to a goal and the problem is to find the best way around the barrier. The tools of thought are put to use in solving problems. Concepts and principles learned through previous experiences are applied to the new situation i.e., to the new problem. Good problems can be used to review past mathematical ideas as well as to sow the

seeds for ideas to be presented at a future time. It is insisted that students should be competent in the basic skills of arithmetic, algebra and geometry. The steps of Polya's approach are analyzed by taking a portion of the lesson each from geometry, algebra and arithmetic.

Geometry is the key to mathematical thinking. Geometry is recognized as a study important for cultural development. Men knew many mathematical facts about circles from very early times. Its importance arises partly from its value in demonstrating the nature and power of pure reason. Technical advances have placed an increasing importance on the geometry of form, size and position, not only in engineering, machine shop and construction industries, but also in landscape architecture, interior decoration and areas of appreciation. Geometry is one of the best grounds of training to prepare high school students for universities and technical institutes. The students realize the ideas of mathematical proof and rigorous logical reasoning through geometrical concepts and also develop mathematical intuition and can acquire independent mathematical creativity (Shanygin and Protasov, 2004). Geometry has been identified as a basic skill by the national council of Teachers of Mathematics.

An example from the lesson transcript of **geometry** is given below:

If the problem is the distance between the ends of a piece of bangle is 4cm and its greatest height is 1 cm. what is the diameter of the full bangle.

There are six sub steps for the step of understanding the problem. In this step students have to recognize what is asked in the problem. So Polya taught teachers to ask students questions such as

- What is the unknown?

- What are the data?
- What is the condition?
- Is the condition sufficient to determine the unknown?
- Draw a figure
- Introduce suitable notation. Separate the various parts of the condition.

The students should continue the sub steps till they find an answer.

For e.g.,

The problem selected from geometry is broken into various parts according to Polya's approach as given below:

Understanding the problem

- What is the unknown?

  Diameter of the full bangle

- What are the data?

  The end of a piece of bangle is 4 cm and its greatest height is 1 cm.

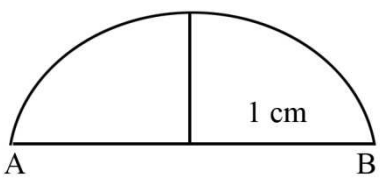
- Is the condition sufficient?

  No.

- What information is missing?

  Data is incomplete

- Draw a figure.



Algebra is often referred to as generalised arithmetic. Algebra is more effective vehicle of complicated meanings. It provides a new and refined approach to the study of abstract mathematical relationship through the use of a new language and a new symbolism.

One of the basic strengths of mathematics is that it allows a modeling of real world entities and problems by mathematical symbols. Then the symbols themselves may be manipulated, processed and operated on to produce a solution.

The curriculum and evaluation standards for school, Mathematics (NCTM, 1989) describe a new vision of curriculum to open kinds of thinking that will help students develop mathematical power. Algebraic thinking plays a key role in this new conception of school mathematics.

An example from the lesson transcript of **algebra** is given below.

Consider *a problem 'The number of girls in a class is four more than the number of boys. In a day when only '8' boys were absent, the number of girls was double the number of boys, how many girls and boys are there in the class?*

According to Polya's approach understanding the problem is found as

Understanding the problem

- What is the unknown?

  Number of girls and boys in the class

- What are the data?

  The number of girls in a class is '4' more than the number of boys.

- What is the condition?

  When '8' boys were absent the number of girls were double the number of boys.

- Is the condition sufficient?

  Yes

- Introduce suitable notation?

  Let the girls be ‘x’ and the number of boys be ‘y’

Arithmetic helps a man in his daily life affairs. The teaching of arithmetic helps in the building up of an appreciation understanding of our number system and an intelligent proficiency in the fundamental processes, the socialization of number experiences that may contribute to the improvement of the common thinking practices.

An example from the lesson transcript of **arithmetic** is shown below.

Simplify $\sqrt{7\frac{1}{2}} \times \sqrt{3\frac{1}{3}}$

Understanding the problem

What is the unknown?

Product of $\sqrt{7\frac{1}{2}}$ and $\sqrt{3\frac{1}{3}}$

What are the data?

Given two fractional roots

Is the condition sufficient?

Yes

The second step of Polya’s approach is:

4.6.3.2 . Devising a plan (Responding to what is asked for) – Polya mentions that there are many reasonable ways to solve problems. The skill at choosing an

appropriate strategy is best learned by solving many problems. A partial list of strategies is included.

- Look for a pattern
- Examine related problems and determine if the same technique can be applied.
- Examine a simpler or special case of the problem and gain insight into the solution of the original problem.
- Make a table
- Make a diagram
- Write an equation
- Use a guess and check
- Work backward
- Identify a sub goal
- Take into account all essential notions involved in the problem. This plan can be analyzed by taking the same example from geometry, algebra and arithmetic.

For e.g., for the above problem from **geometry** the child can use the following steps of planning:

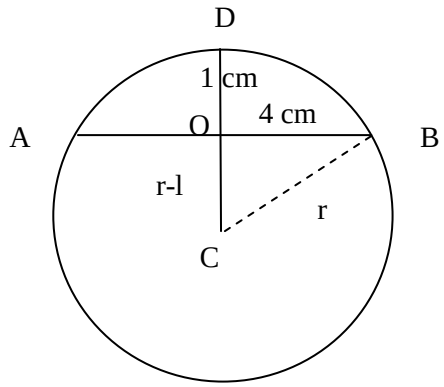
Find the connection between the data and the unknown.

Given AB = 4cm find the value of ‘r’?

Examine a simpler problem and see if the same technique can be applied.

Complete the figure

Draw the diagram



- Which result can be used to find r?

  Line joining the centre of a circle to the midpoint of a chord is perpendicular to the chord.

  Or $r = \sqrt{\left[\frac{\ell}{2}\right]^2 + (d)^2}$ $r = \sqrt{(2)^2 + (r-1)^2}$

  ℓ (length of the chord) =AB= 4cm

  d = distance from the centre to the chord= CO

For the above problem in **algebra** the child can use the following steps of planning. Find the connection between the data and the unknown.

$x = y+4$ - (1)

$y + 4 = 2(y – 8)$

Examine a simpler problem and see if the same technique can be applied.

$y + 4 = 2y –16$ - (2)

For the above problem in **arithmetic**

Simplify $\sqrt{7\frac{1}{2}}\,x \quad \sqrt{3\frac{1}{3}}$

The child can use the following procedure.

Examine a simpler problem and determine if the same technique can be applied.

Simplify $7\frac{1}{2}$ and $3\frac{1}{3}$

$$7\frac{1}{2} = \frac{7 \times 2 + 1}{2} = \frac{15}{2}$$

$$3\frac{1}{3} = \frac{3 \times 3 + 1}{3} = \frac{10}{3}$$

What is the value of $\sqrt{7\frac{1}{2}} \times \sqrt{3\frac{1}{3}}$?

$$\sqrt{7\frac{1}{2}} \times \sqrt{3\frac{1}{3}} = \sqrt{\frac{15}{2}} \times \sqrt{\frac{10}{3}}$$

The third step of Polya's approach is:

4.6.3.3 Carrying out the plan (Developing the result of the response). This step is usually easier than devising the plan. In general all you need is care and patience, given that you have the necessary skills persistent with the plan that you have chosen. If it continues not to work discard it and choose another. Check each step of the plan as you proceed. This may be intuitive checking or a formal proof of each step. Keep an accurate record of your work. The above step is shown using the example of geometry, algebra and arithmetic.

For the above problem in **geometry**, the following steps can be carried.

Which theorem can be used to find the value of r?

Pythagoras Theorem

What is the value of r?

$$r^2 = (r-1)^2 + (2)^2$$

$$\therefore 2r = 5$$

$$r = \frac{5}{2} = \underline{\underline{2.5cm}}$$

What is the relation between radius and diameter?

$$d = 2r$$

What is the value of d?

d = 2 x 2.5 = 5cm

For the above problem in **algebra**, the third step is to carry out the steps planned above. Teacher can ask true heuristic questions to arrive at the solution.

2y-y = 4+16 = 20

Therefore y =20

For the above problem in **arithmetic**

Simplify $\sqrt{7\frac{1}{2}}$ x $\sqrt{3\frac{1}{3}}$

The third step of Polya's approach for the above problem is carried out using the pre-requisite of multiplication of irrational numbers:

What is $\sqrt{x} \times \sqrt{y}$?

$$\sqrt{x} \times \sqrt{y} = \sqrt{xy}$$

$$\sqrt{\frac{15}{2}} \times \sqrt{\frac{10}{3}} = \sqrt{\frac{15\times10}{2\times3}} = \sqrt{\frac{150}{6}} = \sqrt{25} = 5$$

The fourth step of Polya's approach is:

4.6.3.4. Looking back- Here the child has to examine the solution obtained in terms of the original problem.

- Is it reasonable?
- Determine if there is any other method of finding the solution
- If possible determine other related or more general problems for which the technique will work

These and other general problem solving strategies or rules of thumb for successful problem solving are called *heuristics.*

4.6.4 Lesson transcripts for control group

Lesson transcripts were prepared with regard to the prevailing activity oriented method of teaching in order to teach the control group. These lesson transcripts were made taking the same topics that were used for making lesson transcripts for the experimental group.

4.6.5 Mathematical Problem solving ability test

Knowledge base pays an important role in students problem solving performance (Polya, 1973 and Schoenfeld, 1985). As indicated by Polya (1973) "it is hard to have a good idea if we have little knowledge of the subject, and impossible to have it if we have no knowledge. Good ideas are based on past experience and formerly acquired knowledge.

Flewelling and Higginson (2005) state that inquiry, investigations and problem solving "give students the opportunity to use their imagination and to get into the habit of doing so, class room tasks can be broadly categorized into those that have the potential for learning and those that provide opportunities for students to practice applying their previously learnt knowledge or skills". (Diezmann, 2005).

As Polya (1962) stated solving a mathematical problem means finding a way out of a difficulty a way around an obstacle, attaining an aim that was not immediately attainable. Solving problems is the specific achievement of intelligence and intelligence is the specific gift of mankind. Solving problems can be regarded as the most characteristically human activity.

A mathematical problem is a situation which poses a question or defines an objective in the light of some given information or conditions, the individual attempting to answer the question or meet the objective that does not possess an immediate solution, hence the solution process, or acts of solving a mathematical problem, requires active search, prior knowledge of mathematics, and a repertoire of heuristic strategies.

As the achievement of students in the problem solving ability test is one of the dependent variables of the study, the Investigator decided to prepare problem solving ability test. Problem solving involves dealing with situation where the solution is not obvious.

The Investigator developed a problem solving ability test in Mathematics for standard IX. In the present study the problem solving ability test was constructed to

- Judge the pupils mastery of the specified objectives.
- Evaluate the instructional methods adopted.
- Assess pupils analysing and synthesising ability of problems.
- Grade the pupils in terms of their achievement.
- To develop a broader understanding of the application and relevance of mathematics to the real world.

4.6.5.1 Preparation of items for the problem solving ability test

As the preliminary step, the Investigator studied the relevant literature and examined the various scales available for assessing the problem solving ability of the students. The test was prepared by a thorough examination of the content and

objectives. As the preliminary step the Investigator prepared 40 items for the problem solving ability test. In order to make a final selection, more items than the number required for the final test was prepared. Then the Investigator in consultation with the mathematics teachers in schools and in consultation with experts in the field of mathematics (the list of experts is given in Appendix-XIV), with an intention to know the appropriateness and clarity of the items to be included in the problem solving test discarded 8 items and retained 32 items. Only the items which truly check the problem solving ability were selected in this step. In the preparation and standardisation of the problem solving ability test, the following sequence was adopted.

I. Choosing the course content.

   The test items were selected from a chapter of Geometry (circles), Arithmetic (Irrational Numbers) and Algebra (pairs of Equations) of std IX students studying under state syllabus.

II. Deciding the teaching objectives.

   The problem solving ability test was constructed keeping in view the higher level objectives.

In mathematics, the key to solving any problem is applying current knowledge in such a way that the answer is obtained. Applying the known to understand the unknown is the most fundamental of all mathematical principles. The power of finding the unknown result from the known facts was made possible for the pupil by using the various steps of Polya's approach.

Thirty two test items were selected for the pilot test. Out of the 32 items, ten questions were selected from circles, ten questions from Arithmetic and

twelve questions from Algebra. The concepts to be developed, the principles to be formulated, the procedure adopted for developing rules and equations and the process leading to problem solving were carefully identified. Problems from the three areas of geometry, Arithmetic and Algebra were selected in order to meet the instructional objectives.

4.6.5.2 Objectives of problem solving ability test on the circles in geometry.

- To develop competency in comprehending properties of chords.
- To develop competency in analyzing the problems and applying relevant conditions.
- To develop the skill of construction of circumcircle.
- To train them in the techniques of the discovery of truth.

The problem from circles involved the concepts; perpendicular from the centre of a circle to a chord, bisects the chord, length of any chord is calculated using the formula $l = 2\sqrt{r^2 - d^2}$, and the analysis of various theorems on congruency of triangles as ASA theorem, RHS theorem, SAS theorem and construction of circumcircle . These problems are often closed–ended problems.

Analysis: This behaviour level is the highest of the cognitive domain. It comprises the most complex behaviour. Analysis items require a non-routine application of concepts. Using Polya's heuristic steps the child tried to detect the relationships, patterns, the organization, use of concepts and operations.

4.6.5.3 Objectives of problem solving ability test on the irrational number in arithmetic.

1. To develop competency in comprehending computations related to irrational numbers.

2. To develop ability in applying properties of irrational numbers and to make proper approximations.
3. To develop skill of representing irrational numbers using numberline.
4. To acquaint them with effective methods of clear impartial thinking.

The problems from Arithmetic involved comprehending the values of irrational number of the form i.e., $\sqrt{80}-\sqrt{20}$ simplifying it, analyzing and finding out which irrational number is largest, rationalization and simplification of irrational numbers and testing pupil's skill of representing $\sqrt{3}$ on the number line. The child tried to solve these problems using Polya's approach.

4.6.5.4 Objectives of problem solving ability test for algebra

- To develop competency in comprehending problems related to algebra.
- To develop ability in analyzing a word problem and representing it using a new language and a new symbolism
- To instill in the pupils an appreciation for the significance of logical demonstration.
- To acquaint them with effective methods of clear impartial thinking, critical evaluation and intelligent generalization.
- To introduce them to the meaning of mathematical rigour and precision.

Every problem in algebra pre-supposes the ability to translate a verbal sentence into algebraic shorthand and a systematic study. Such translation should form the starting point for the study of problems.

Problems in Algebra was to find the value of variables given a particular condition They were problems to frame equations and to find the value of the variables. The solution to the problem involved the understanding of distinct mathematical concepts and the use of mathematical skills as finding the value of an unknown variable given the sufficient conditions.

A hundred rupee note was changed to ten rupee notes and twenty rupee notes. Eight notes in all. How many tens and how many twenties?

Polya's Heuristic strategy adopted by the teacher helped children to master the process of analysis of the problem.

The name of the examination, title, maximum marks, time and the necessary steps to be followed using Polya's approach was mentioned. Maximum marks allotted for the problem solving ability test was 50 and time given was 90 minutes. Questions from the three chapters of circles, irrational numbers and pairs of equations were arranged in a systematic manner. The different forms of questions easy, average, and difficult of the problem solving ability test was arranged in a random manner. All sufficient instructions were given.

(Problems solving ability test is given in Appendix-VI)

4.6.5.5 Pilot Study

In the case of a standardised test, the selection of items will be made on the basis of quantitative evidences, collected by statistical procedures. Therefore a preliminary testing will have to be conducted. After selecting the sample,

arrangements are made with the authorities for a proper conduct of the test, under satisfactory examination conditions. It was conducted under identical conditions. The preliminary test was administered to a random sample of students belonging to the category for which the test is made. A sample of 100 students was taken from St. Mary's A. I. G. H S for administering the preliminary test.

4.6.5.6 Item analysis

Item analysis is an integral part of both reliability and validity of the test through the process of difficulty index and discriminating power. Thus, the procedure of Item analysis helps to select the very best items for final test. The researcher had done the item analysis using the following procedure.

The 100 script obtained after the preliminary test were scored and the total score for each script was noted. Then these were arranged in the descending order of the total scores and the highest 27% and the lowest 27% with respect to the total scores were separated. The number of students in the highest 27% is taken as the upper group and the lowest 27% is taken as the lower group.

Since the number of students in the preliminary test was 100 the number of students in the upper and lower group will be 27 each. For example for the first question in preliminary problem solving ability test U is 21 and L is 3.

- **Determining the difficulty index of an item**

The difficulty index of an item is represented by the percentage of students who responded to it correctly. More percentage of correct response, easier is the item. If 'N' is the number of examinees in the upper or lower group and if 'U' & 'L' are the numbers in the two groups in the order, that have given correct response to an item, the difficulty index, will be indicated by the relation:

$$D\,I = \frac{U + L}{2N}$$

If the number of students in the upper group who have answered the first question correctly is 21 then U=21, if the number of students in the lower group who have answered the first question correctly is 3 then L=3, number of students in any one group is 27, hence N=27. Thus, difficulty index, DI= (U + L)/2N=(21+3)/2 x 27=0.4.

Table 4.1a

Items selected for the final mathematical problem solving ability test based on difficulty index

Sl.No.	**Serial no. of the items in the draft test**	**Difficulty index D.I = U+L/2N**
1	1	0.41
2	2	0.46
3	4	0.4
4	5	0.41
5	7	0.4
6	8	0.4
7	10	0.35
8	11	0.41
9	12	0.45
10	13	0.3
11	14	0.44
12	15	0.44
13	17	0.35
14	20	0.44
15	23	0.3
16	25	0.45
17	28	0.3
18	31	0.32

- **Determining the discriminating power**

The discriminating power of an item is evidenced by its power to discriminate between the upper and the lower groups. The difference between the correct responses in the two groups will be an indication of how far it can discriminate the true groups. Larger the difference, more is the power to discriminate.

$$D.P = (U-L)/ N$$

Where U & L are the number of correct responses in the upper and lower groups respectively and N is the number of cases in each group.

If the number of students in the upper group who have answered the first question correctly is 21 then U=21, if the number of students in the lower group who have answered the first question correctly is 3 then L=3, number of students in any one group is 27, hence N=27. Thus, discriminating power, DP= (U-L)/N= (21-3)/27=0.6.

Table 4.1b

Items selected for the final mathematical problem solving ability test based on discriminating power

Sl.No.	Serial no. of the items in the draft test	Discriminating power D.P=(U-L)/N
1	1	0.61
2	2	0.63
3	4	0.5
4	5	0.62
5	7	0.35
6	8	0.5
7	10	0.4
8	11	0.4
9	12	0.5
10	13	0.37
11	14	0.51
12	15	0.61
13	17	0.4
14	20	0.59
15	23	0.4
16	25	0.62
17	28	0.4
18	31	0.37

The difficulty index and discriminating power of each item of the problem solving ability test is given in Appendix No. XI

Criteria for selection of items

On the basis of the difficulty index and discriminating power considered at the same time, items are rated.

1. The difficulty index was fixed from 0.3 to 0.5 with the additional restriction that all possible value in the range should be covered.

2. Within the difficulty criteria specified above it was decided to select items with the maximum discriminating power. Items having discriminating power ranging from 0.3 to 0.6 are included in the final test.

4.6.5.7 Preparation of the Final Test

18 items were selected for the final problem solving ability test. Copy of the test is given in the Appendix- .VII

Design developed for problem solving ability test

The researcher developed the design of the test, in terms of the objectives and determined the relative weightage to each objective and sub units in the content. It was decided to include short answer and essay type questions.

a) Weightage given to instructional objectives in the mathematical problem solving ability test

In order to serve the purpose of the test, due weightage was given to higher level objectives. This is ensured to measure mainly the cognitive domain behaviours.

Table 4.2

Weightage to objectives in the mathematical problem solving ability test

Sl. No.	Objectives	Marks	%
1	Understanding (to find the values of variables)	3	12
2	Application (To analyse and solve problems)	19	76
3	Skill (To solve problems)	3	12
	Total	25	100

b) Weightage given to content areas in the mathematical problem solving ability test

Content is limited to a single chapter each from geometry, algebra and arithmetic.

Based on item analysis, marks were allotted for geometry, algebra and arithmetic.

Table 4.3

Weightage to Content in the mathematical problem solving ability test

Sl.No.	Objectives	Marks	%
1	Geometry (Circles)	10	40
2	Algebra (Pairs of equations)	8.5	34
3	Arithmetic (Irrational numbers)	6.5	26
	Total	25	100

c) Weightage given to form of questions in the mathematical problem solving ability test

In order to test the problem solving ability of the child, short answer and essay type questions were included.

Table 4.4

Weightage to form of Questions in the mathematical problem solving ability test

Sl.No.	Objectives	Marks	%
1	Short answer	22	88
2	Essay	3	12
	Total	25	100

d) Weightage given to difficulty level in the mathematical problem solving ability test

By considering all levels of the students, the researcher decided sixty two percentage of the items of average difficulty, with sixteen percentage of easy and twenty two percentage of difficult questions.

Table 4.5

Weightage to difficulty level in the mathematical problem solving ability test

Sl.No.	Objectives	Marks	%
1	Easy	4	16
2	Average	15 ½	62
3	Difficult	5 ½	22
	Total	25	100

4.6.5.8 Blueprint of problem solving ability test

Blueprint is a three dimensional chart showing weightage to content, objectives and form of questions.

Table 4.6

Blueprint of mathematical problem solving ability test

Objectives	**Understanding**		**Application**		**Skill**		**Total**
Form of question / Content	S.A	Essay	S.A	Essay	S.A	Essay	
Geometry			$(2)_1$ $(1)_2$ $(2)_{1½}$			$(1)_3$	10
Algebra	$(3)_1$		$(4)_1$ $(1)_{1½}$				8 ½
Arithmetic			$(2)_1$ $(1)_2$ $(1)_{2½}$				6 ½
Total	3		19		3		25

The figure inside the bracket indicates the number of questions and the figure out side the bracket indicates the mark of each question in the problem solving ability test.

4.6.5.9 Preparation of the scheme for evaluation

In order to ensure the objectivity of the test items, value points were prepared. The scoring is made strictly in accordance with a pre designed scheme of evaluation. The marking scheme was prepared and the answer scripts were scored by the Investigator. Marking scheme is given in Appendix No. X.

4.6.5.10 Validity and Reliability of the test

The validity and reliability of the problem solving ability test were assessed before it was used for the final data collection. In the words of Messick (1989), validity is an integrated evaluative judgment of the degree to which empirical evidence and theoretical rationales support the adequacy and appropriateness of inferences and actions based on test scores or other modes of assessments.

Validity is the most important quality needed for a test. Lindiquest (1963) defines validity as follows:

The validity of a test may be defined as the accuracy with which it measures what it is intended to measure. Reliability of a test refers to the degree of consistency with which it measures what it is intended to measure.

- **Determination of validity**

A test is said to be valid if it measures what it intends to measure. In the present study the researcher determined the content validity, empirical validity, construct validity and concurrent validity of the test.

- **Content validity**

Content validity is concerned with the extent to which the test is representative of a defined body of content consisting of topic and process (Wiersma, 1995). This involves proper coverage of the content to be learned as well as the instructional objectives to be realized. A design was prepared which shows weightage to each sub unit and instructional objectives. Items were constructed for evaluating these objectives. Then the items were verified by the supervising teacher and thoroughly examined and corrected by senior teachers in the field. (List of teachers is given in the Appendix No. XIV). By this process the researcher ensured the content validity.

- **Empirical validity or statistical validity**

Statistical validity is similar to internal validity. Here the question is, was the observed relationship between the independent and dependent variables a true cause effect relationship or was it accidental or was the number of subjects so small that the result happened is purely by chance? (Burney, 2001). "The

empirical validity of the test is to be calculated by correlating the scores of the test with marks of a recently conducted test obtained from the school" (Ebel, 1991).

Here the empirical validity of the test is calculated by correlating the scores of the test with marks of a recently conducted test obtained from the school. Here empirical validity of the test was calculated by correlating the test scores with the monthly examination score for maths of the same students. The coefficient of correlation obtained by calculating the product moment correlation is 0.74. This ensures the empirical validity of the prepared test.

- **Construct validity**

In this type of validity, agreement is sought on the operationalized forms of a construct, clarifying what we mean when we use this construct. Hence in this form of validity, the articulation of the construct is important, i.e., the researcher's understanding of this construct should be similar to that what is generally accepted to be the construct.

To establish construct validity, the Investigator assured that the construction of a particular issue agreed with other constructions of the same underlying issue. It was also checked by rooting the researcher's construction in a wide literature search which ensured the meaning of a particular construct. When the confirming and refuting evidence was balanced, the researcher was in a position to demonstrate construct validity.

- **Concurrent validity**

As per Cohen (2008) in concurrent validity the data gathered from using one instrument must correlate highly with data gathered from using another instrument.

In order to test the concurrent validity of the problem solving ability test, the researcher observed the students working on a problem. As the result agreed, concurred that according to given criteria for problem solving ability, the researcher, was able to say that the student was good at problem solving than the researcher had arrived at that judgment simply from using one instrument.

- **Reliability of the test**

Reliability refers to the degree to which a tool would produce the same result from one occasion to another. A test is reliable, if it consistently yields the same or nearly the same ranks over repeated administration. (Tomkubiszyn, 1993). Reliability is a necessary ingredient of validity but it is not sufficient to ensure validity.

In the present study the reliability co efficient of the problem solving ability test was calculated using the split half method.

- **Split half method**

The problem solving ability test is divided into two equal halves and each half is considered as a separate test, these independent subjects are then used as a source of the two independent scores needed for reliability estimation. Here the researcher considered odd items and even items separately to develop the half tests.

In the present study the reliability coefficient of the problem solving ability test was calculated using the split half method. The scores obtained for each of the '100' students for 'odd' and even items were calculated separately. The two sets of scores were subjected to Karl Pearson's product moment test of correlation. The resulting reliability co-efficient was found to be 0.72. This being the reliability for

half scores the reliability for the whole test was calculated using the Spearman brown prophecy formula.

$$R = \frac{2r}{1+r}$$

R = reliability co – efficient for the whole test.

r = reliability co – efficient of the half test.

$$R = \frac{2 \times .72}{1 + .72} = .8$$

The high value of R shows that the problem solving ability test prepared by the Investigator is a highly reliable tool.

4.6.6 Mathematical problem Creativity Test

- **Creativity**

One of the popular meanings of creativity is regarded as a process by which something new, either an idea or an object in a new form or arrangement is produced. Torrance (1965) defined that "Creativity is a process of becoming sensitive to problems, deficiencies, gap in knowledge, missing elements, disharmonies and so on, identifying the difficulty, searching for solutions, making guesses or formulating hypotheses about the deficiencies, testing the hypotheses and possibility of modifying and retesting them and finally communicating the result. Creativity is not about inventing something totally new but it is about making new meaningful connections. Creativity is your ability to connect pieces of knowledge to come up with a solution. According to Jay and Perkins (1997) the act of finding and formulating a problem is a key aspect of creative thinking and creative performance in many fields, an act that is distinct from and perhaps more important than problem solving.

The factors of creativity are tentatively described as associative and ideational fluency, originality adaptive and spontaneous flexibility and ability to make logical evaluations. Creativity involves the ability to produce original ideas, to perceive new relationships among unrelated things. It is the ability of mind, like intelligence and is processed by all individuals. Four approaches have been used to understand the concept of creativity. These are called the four P's, that is the product of creative thinking, the process of creative thinking, the person who is creative and the environment in which the creation comes about.

Kohler (1997) claimed that the inadequate success of students in mathematics might be due to lack of creative approaches in teaching and learning. Creativity is uniqueness. It is thinking in divergent directions. Creativity suggests utmost freedom of human thought. The creative individual is free to choose any path that is open to him. It is viewed as involving the production of as many answers as possible to a given problem.

Creative mathematics develops the ability to analyse a given problem in many ways, observe patterns, see likeness and differences and in the light of what has worked in similar situations, to decide upon a method of attack in an unfamiliar situation. Creative mathematicians are persons who tend to generalize particular results either by finding a common thread of induction, or by being similar pattern by analogy and who offer more than one acceptable uncommon solution to a problem. When the creative potentialities of the individuals are not utilized in achieving something constructive, it is a mere national waste.

- **Thinking – Main spring of creativity**

Whenever we are confronted with a problem that defines immediate solution we begin to think. Our past experiences can be a reliable guide. At times we might discard the past and think afresh. Guilford (1959) identifies the following characteristics in creative thinking.

a. Ability to change one's approach to a problem

b. Coping with ideas that are both relevant and unusual

4.6.6.1 Description of Mathematical Problem Creativity test

Chauhan (1977) defined creativity in mathematics or mathematical problem creating ability as the ability to generate information or ideas from given information or ideas in mathematical situation, emphasis being on quantity and quality. Problem solving and problem posing were considered to be two important aspects of mathematical creativity. Polya (1965) suggested problem solving method as a more effective strategy to develop mathematical creativity. Several researchers in the field characterized mathematical creativity in the contexts of various factors. The concept of fluency flexibility and originality were also applied to the concept of mathematical creativity.

The National Council of Teachers of Mathematics (NCTM, 2000) indicated that students should develop their "flexibility in exploring mathematical ideas and

trying alternative solution paths". Hiebert et al. (1997) indicated that students should be provided with problem-solving tasks that for which they "have no memorized rules, nor for which they perceive there is one right solution method". It is important to study teaching and learning alternative solutions in mathematical problem solving because "you can learn more from solving one problem in many different ways than you can from solving many different problems, each in only one way" (an aphorism of unknown origin, cited in Silver, Ghousseini, Gosen, Charalambous, & Strawhun, 2005).

Alternative solutions are an important feature of effective problem-based mathematics instruction (Cai, 2003). Teaching mathematics through problem solving provides a learning environment for students to explore problems on their own and to invent ways to solve the problems. Such activities allow them to facilitate connections of related ideas, to consolidate their mathematical knowledge, and to think creatively (Polya, 1973; Kalman, 2004 & Krulik & Rudnick, 1994). Teaching through problem solving offers the promise of fostering student learning.

The relationship among problem solving, posing problem activities and mathematical problem creativity in Polya's approach is illustrated in the following table:

Table 4.7

Relationship between problem solving, posing problem activities and mathematical problem creativity

Solving problem	**Posing problem**	**Mathematical Problem creativity**
Students analyze, identify, select some different method of solution or strategies of an open ended problem	Students compile some new problem or poses new problems	Fluency
Students solve the problems by various strategies	Students pose some new different problems by using Polya's steps (what if not technique)	Flexibility
Students discuss some different method of solution or strategies & result of each solution.	Students test some problem and then pose different problems	Originality

Changing some variables from a given problem to create new problems, posing open ended questions, investigating a problem from many different aspects giving conditions on which a traditional mathematical exercise was presented to develop and answer new problems, formulating a sequence of problems from a given situation in story form were some procedures observed to determine the mathematical problem creating ability.

Creative problem solving is considered as a process in which open ended questions were used and which was challenging and which required divergent

thinking. The goal in creative thinking is to motivate the students to think and do something. In open ended questions, various alternative ways of solving a problem are searched.

4.6.6.2 Preparation of items

This test tool composed of three categories fluency which is determined by number of responses, flexibility which is determined by number of different kinds of responses and originality which is decided by degree of uniqueness of responses and these are the three factors of creativity.

Mathematical problem creativity is a trait differentially distributed among individuals and includes the abilities of fluency, flexibility and originality measurement of which is possible with the help of Investigators test of mathematical problem creativity.

The test which was developed by the Investigator with the help of supervising teacher is meant to identify mathematical problem creativity talents of secondary school students. The theoretical frame work for the construction of the test was provided by empirical studies on the nature of mathematical creativity. The tasks pertaining to fluency, flexibility and originality have been used in mathematical problem creativity test. An objective that specifies creativity as its learning level required students to think divergently to originate ideas, hypotheses or methods. Non rational inter play leaves room for open ended thoughts that can lead to a mental state in which new ideas are possible. Portions from the three areas of geometry, algebra and arithmetic were given to the students to create problems. Altogether 20 tests were prepared in consultation with experts in the field Problem creating ability test is given in the Appendix No. VIII.

4.6.6.3 Conduct of the test

Creativity enriched mathematical problem can be developed to assess mathematical creativity. A creativity enriched mathematical problem is one that can be solved by various approaches and permits many possible answers.

Prior to conducting the test, the subjects were instructed by the tester for 10 minutes on how to complete their answer sheets. They were given 60 minutes to present various types of original and unique answers.

In order to develop creativity, students were given open ended problems in which they posed various questions to develop more creative approaches to mathematics. They were free to question, make mistakes and disagree with ideas even that of teacher. It is claimed that through the use of such tasks and activities teachers can increase their students capacity with respect to the core dimensions of creativity namely fluency, flexibility and originality.

In order to test mathematical creativity of children open ended problems were given from three areas of geometry (circles), algebra (pairs of equations) and arithmetic (irrational numbers). A semi structured problem posing situation is given to the children, they are asked to explore the structure of that situation and to complete it by applying knowledge, skills, concepts and relationships from their previous mathematics experience.

Geometry is recognized as a study important for cultural development. It is the key to mathematical thinking. From time immemorial man has found that concepts of size, shape and position are ever prominent in the pattern of his environment and that the geometric principles of congruency and similarity are implanted in the very nature of things. Because of its wide application in art,

architecture and engineering the triangle is probably the most important figure studied in plane geometry. The idea of equality, similarity and congruence comes in circles. Concept of circles has wider applications in higher classes. Here the topic selected from geometry was circles of Std IX. As ideas of right angled triangle and properties of chords are used in the study of circles, twelve semi structured problems, five from circles and seven from triangles were given. The students had to put some creative effort to solve these problems which distinguish it from an exercise.

Arithmetic is the most practical branch having maximum utilitarian value almost to all human beings in all walks of life. For problem creating ability test the chapter irrational numbers from arithmetic was taken. It is used in learning other branches of mathematics and for higher studies in mathematics. Students were asked to frame problems which are multiples of $\sqrt{2}$, $\sqrt{3}$, $\sqrt{8}$, $\sqrt{10}$ and $\sqrt{50}$.

In a true sense algebra is a generalized arithmetic. Symbolism and generalization are the two main characters which may be observed in the structure and processes of algebra. The power of algebra lies in its structure and process of generalization. For problem creating ability test, the questions from algebra were to frame equations in one variable and two variables, so that the solution can be an odd number or an even number and frame an equation in two variables so that the solution is an even number.

4.6.6.5 Preparation for the scheme of evaluation

Balka (1974) suggested criteria for measuring mathematical creativity.

1. Ability to generalize particular results either by finding common threads of induction or by determining patterns by analogy in a mathematical situation.
2. Ability to create general mathematical problem into specific sub problems or ability to see problems on data.
3. Ability to see what is missing in mathematical problem and ask questions that will lead to tell in missing mathematical information.
4. Ability to see trends and consequences in a mathematical situation.

4.6.6.6 The computation of the scores

The problems created by the students were categorized and scores on fluency, flexibility and originality categories were arrived at. The total of these three scores was considered as mathematical problem creating ability score.

Marking method and standard

The method and standard of marking the responses are as follows:

1) All types of responses to items are analyzed and recorded.

2) Same types of responses are selected and classified.

3) Scores are given by categorized responses where score of fluency, flexibility, and originality are analysed. Each scoring method is suggested as below:

- **Computation of fluency score**

Fluency: How many correct answers exist with a categorised response? When a student makes multiple correct answers in a category, the score can be given according to the answers. Fluency is measured in terms of the total no. of problems a subject created. A score of 1 was awarded to each scorable problem.

No credit was given to any response which was incompatible with the instructions given. Responses which were repeated were not scored.

- **Computation of flexibility score**

Flexibility: How many types of categorised response a student can make? Flexibility score is the number of different methods or categories of ideas. For example, if a student's answers are classified into 15 categories of responses, then flexibility score is 15. The nature and type of each correct response was observed. The responses were grouped under appropriate flexibility categories. A score of 'l' was given to each of the different categories of responses. The total no. of such scores was computed as flexibility score of the respondents.

- **Computation of originality scores**

Originality: How original an answer is where no other students could think of? That is, originality score reflects the relative rarity of response. Originality is defined as statistical infrequency of responses. The originality score is obtained by giving weight for correct responses within a range of percentage of students giving the same response. Following this the originality score of a subject was determined as follows:

- The percentage of subjects in the sample who gave the same response was calculated
- No weightage for originality was given to any scorable response given by more than 5% of the sample
- Originality weights of 1, 2, 3, 4 and 5 respectively were assigned to responses by 5%, 4%, 3%, 2% and 1% of the sample.
- Originality weights for different scorable responses given by each subject were summed up to obtain his/her originality score.

Example:

Create as many problems as you can, using the data given below. Length of a chord is 8 cm. The various problems that can be created based on fluency, flexibility and originality are:

1. Draw a circle having a length of its chord as 8 cm
2. What is the radius of the smallest circle that can be drawn given the distance between two points A and B on the circle is 8 cm.
3. A chord of length 8 cm is drawn in a circle which is 3 cm away from the centre. Calculate the radius of the circle.
4. In a circle of radius 5cm two parallel chords of lengths 6cm and 8cm are drawn on either side of the centre. What is the distance between them?
5. In a circle of radius 5cm, find the distance from the centre to a chord of length 8 cm.

4.6.6.6 Standardisation of mathematical problem creating ability test

More items than what is required in the final test are given in the preliminary test. The test was administered to a random sample of students belonging to the category. Pilot test was administered to a sample of '100' students.

4.6.6.7 Item analysis:

- **Determining the difficulty index**

It is the process of determining the difficulty index and discriminating power of a test. The difficulty index is calculated using the formula.

$$DI = \frac{U+L}{2N}$$

Where 'U' denotes the number of students answering an item correctly in the upper group (upper 27%), 'L' denotes the number of students answering an item correctly in the lower group (lower 27%). 'N' is the no. of students in any one group.

For example, If the number of students in the upper group who have answered the first question correctly is 18 then U=18, if the number of students in the lower group who have answered the first question correctly is 9 then L=9, number of students in any one group is 27, hence N=27. Thus, difficulty index, DI= (U+L)/2N= (18+9)/2 x 27=0.5.

Table 4.8a

Items selected for the final mathematical problem creating ability test based on difficulty index

Sl.No.	**Serial no. of the items in the draft test**	**Difficulty index DI = (U+L)/2N**
1	1	0.5
2	3	0.44
3	5	0.33
4	7	0.48
5	9	0.44
6	14	0.5
7	19	0.35
8	17	0.43
9	16	0.46
10	12	0.43

Determining the discriminating power

Discriminating power is calculated using the formula

$$D.P = \frac{U-L}{N}$$

Where 'U' denotes the number of students answering an item correctly in the upper group (upper 27%), 'L' denotes the number of students answering an item correctly in the lower group (lower 27%). 'N' is the no. of students in any one group.

If the number of students in the upper group who have answered the first question correctly is 18 then U=18, if the number of students in the lower group who have answered the first question correctly is 9 then L=9, number of students in any one group is 27, hence N=27. Thus, discriminating power, DP= (U-L)/N= (18-9)/27=0.3.

Table 4.8b

Items selected for the final mathematical problem creating ability test based on discriminating power

Sl.No.	**Serial no. of the items in the draft test**	**Discriminating power DP=(U-L)/N**
1	1	0.33
2	3	0.44
3	5	0.52
4	7	0.52
5	9	0.59
6	14	0.56
7	19	0.56
8	17	0.56
9	16	0.55
10	12	0.63

The difficulty index and discriminating power of problem creating ability test is given under Appendix No. XII.

- **Criteria for selection of items**

  Items whose difficulty index ranging from 0.3 to 0.5 and discriminating power ranging from 0.3 to 0.6 are included in the final test

4.6.6.8 Preparation of final test:

Questions from geometry (circles, triangles), arithmetic (irrational numbers) and algebra (pairs of equations) are arranged in a sequential order. Necessary instructions are given to create problems.

In the section of problem creating ability test from geometry, there were 6 questions. In these questions, students were asked to create problems from circles if the radius of a circle is 6 cm, diameter of a circle is 10 cm , and length of a chord is 12 cm. Students were asked to create problems in triangles given, one of the angles of a triangle is 90^o, one of the angles of a triangle is 45^o one of the sides of a triangle is 13 cm. The students could add more relevant data to make the question complete. Problem creating ability test was taken from arithmetic. Here the students were given open-ended problems to create, e.g., the solution of the problem should be a multiple of $\sqrt{2}$, $\sqrt{3}$. Under the third section of the problem creating ability test, students were asked to create problems from algebra. The questions given were to frame equations involving one variable so that the solution is an even number and odd number.

- **Selection of the sample for the final test**

A convenient sample representing the population is selected and the final problem creating ability test is administered.

4.6.6.8 Scoring of the answer sheets

The answer scripts are valued based on the scheme of evaluation. The criteria regarding fluency, flexibility and originality is noted.

❖ **Determination of validity and reliability**

Validity is the extent to which a tool measures what it is intended to measure. In the present study, the researcher determined the concurrent validity, content validity and face validity.

❖ **Concurrent Validity**

It is the degree to which scores on one test correlate to scores on another test when both tests are administered in the same time frame. Concurrent validity of problem creating ability test was established by correlating the scores with another problem creating ability test prepared by Sharma (2013) which was administered simultaneously. High correlation of 0.7 between the two tests establishes the concurrent validity. The test is given in Appendix – XIII.

❖ **Content validity**

It is the degree to which a test measures an intended content area. To demonstrate this form of validity, the tool must show that it fairly and comprehensively covers the domain or items that it purports to cover.

Problem creating ability test was framed so it covered all the major aspects of the content of circles, irrational numbers and pairs of equations. The test was a proper representation of the content. It measured what the student was taught and were expected to learn in the treatments. This ensured the content validity of the test.

❖ **Face validity**

The face validity of the test was determined. The opinion of experts in this field was taken into consideration while preparing the test and necessary modifications were made according to their suggestions.

❖ **Reliability**

A test is reliable if it consistently yields the same or nearly the same ranks over repeated administration.

In the present study the reliability coefficient of the problem creating ability test was calculated using the split half method. The scores obtained for each of the '100' students for odd and even items were calculated separately. The two sets of scores were subjected to Karl Pearson's product moment test of correlation. The resulting reliability co efficient was found to be .6. This being the reliability for half scores, the reliability for the whole test was calculated using the spearman brown prophecy formula.

$$R = \frac{2r}{1+r}$$

R is the reliability co – efficient for the whole test

r is the reliability co –efficient of the half test.

$$R = \frac{2 \times 0.6}{1 + 0.6} = \frac{1.2}{1.6} = 0.75$$

This shows that the problem creating ability test prepared by the Investigator was reliable.

4.6.7 Statistical techniques adopted

The pre – test and post –test scores of the experimental and control groups were consolidated. The following statistical techniques were used.

1. Percentages
2. Mann-Whitney U test
3. Testing the significance of mean difference.
4. ANOVA
5. ANCOVA
6. Student-Newman-Keul test

The details of the analysis of data using relevant statistical methods have been compiled in the next chapter.