CHAPTER – IV

DESIGN OF THE STUDY

4.1 Introduction

Research methods describe the various steps of the plan of attack to be adopted in solving the research problem, such as the manner in which the problem is formulated, the definition of terms, the choice of subjects for investigation, the validation of data gathering tools, collection of data, analysis and interpretation of data and the process of inferences and generalizations.

4.2 Method selected for the study

Since the aim of the study is to find out the effect of metacognitive strategies, the experimental method was found to be the suitable method to conduct research.

Experimentation or experimental research differs from descriptive studies in which researcher has some degree of control over the variables involved and the conditions under which the variables are observed. Experimental method provides much control and therefore establishes a systematic and logical association between manipulated factors and observed effects.

Best.J.W(1997) are of the opinion that "the experiment is the only means of setting disputes regarding educational practice, the only way of verifying educations improvements and the only way of establishing a cumulative tradition in which improvements can be introduced."

4.3 Research design
Research design

Variables

Experimental design

Sample
Experimental group: 35
Control group: 35

Experimental group

Control group

Statistical measure

Tools
1. Achievement in physics
2. Metacognitive awareness
3. Attitude towards learning physics
4. Study habit
5. Home learning environment

Descriptive analysis
Mean, S.D

Differential analysis
t-test, ANOVA
Effect size, Omega square

Relational analysis
Correlation
Multiple regression

Independent variable
Metacognitive strategies

Dependent variable
Achievement in physics

Intervening variables
1. Metacognitive awareness
2. Attitude towards learning physics
3. Study habit
4. Home learning environment
4.4 Experimental design

An experimental design to the research is what a blueprint to an architect. It provides the researcher an opportunity for comparisons 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 statistical analysis of data.

The design selected for the present study is pre- and post-test quasi experimental design with experimental and control group. In this design the control group and experimental groups are pre-assembled groups such as intact classes, for framing experimental and control groups. The pre-assembled groups are selected and are administered pre-test. The pretest scores are analysed to show that means and standard deviations of the two groups do not differ significantly. If the present scores for the groups are not equivalent, the experimenter may proceed with the conduct of the experiment by using the technique of analysis of co-variance to compensate for this lack of equivalency between the groups. Once the two groups are obtained, randomly one group is to be assigned to experimental treatment and another one to the controlled condition. After determining the groups the experimental treatment is administered to the experimental group. Now the post-test is given to both the groups. The difference between the pretest and post-test scores are compared with help of appropriate statistical test to ascertain the effect of the treatment.
Fig.4.1. Experimental design flow chart

In this study experimenter seeks to study the effectiveness of metacognitive strategies in achievement of physics at higher secondary level. Electrostatics topic in XII standard text book was selected as the topic of the study. Control group and experimental groups were selected based on the quarterly exam marks. The pre assembled groups are administered pre-test. The pre-test scores are analysed to show that the
mean and standard deviations of the two groups do not differ significantly. Once the two groups obtained, randomly one group is

assigned control group and another group is assigned as experimental group. Experimental group will be taught through the metacognitive strategies and the control group by conventional method for the period of 15 days. For both groups, instructions were carried out by same teacher so that variation in terms of teaching competence in the experiment is minimized. The experimental and control groups are administrated with post-test as the measure of the dependent variable. The difference between the pre-test and post-test scores and mean of these differences for each group will be determined. To ascertain whether the performance in physics of the experimental group is sufficiently great as a result of teaching through metacognitive strategies, statistical test will be applied to the significance of the experimental and the control group. The amount of the time allotted for the experiment was equal for both groups.

4.5 Variables in the study

Something that can change in value and can be measured is a variable. It can be an aspect of an experimental situation or a characteristic that changes in different individuals. For an experimental study there are independent and dependent variables.

Independent variable

It is the variable which is manipulated by the experimenter or the variable, which is suspected of being the cause in the experiment is called independent variable often called the treatment variable. In this experiment metacognitive strategies are the independent variable.
**Dependent variable**

The dependent variable is the condition or characteristic that appears, disappears or changes as the experimenter introduces, removes or changes independent variable. The variable that is dependent on something is called dependent variable. The dependent variable is measured before and after the manipulation of the independent variable. The dependent variable used in this study is achievement in physics.

**Intervening variable**

An intervening variable is a factor which affects the observed phenomenon but cannot be seen and measured and manipulated. The intervening variables considered are as follows:

- Metacognitive awareness
- Students attitude towards learning physics
- Home learning environment
- Study habit

**4.6 Threats to internal validity**

Experimental design should enhance experimental validity. The careful control of extraneous variables characterizes good experimental research. There are usually many possible ways to explain the outcomes of a study. The possibility of such alternative explanations is usually referred to "Threats of internal validity".

Threats to validity lead to ambiguous explanation of the data. According to Aggarwall J.C.(1966) the threats of experimental validity may be classified into two categories:

- Threats to internal validity
- Threats to external validity
Internal validity depends upon the ways in which the process of experimentation itself may affect the results obtained.

**History**

Unanticipated events affect the dependent variable and this may occur while the experiment is in progress. On occasion, one or more unanticipated and unplanned events which can affect the responses of the subjects may occur during the course of the study. Such events are referred to "History threat" in educational research.

During this experiment unexpected events did not occur. This threat was eliminated.

**Selection**

In this study, two groups each having 35 students having physics as one of the subject were selected. There were learning disabled and non disabled and they were Computer, Maths and Biology branch students. There was no selection threat occurred.

**Testing**

The effect of taking one test upon the scores of a subsequent test is called testing threat. In experimental studies it is common to test subjects at the beginning and end of the study. By testing we mean the use of any form of instrument. If considerable improvement is found in the post-test score, the researcher may conclude that the improvement is due to the experimentation. An alternative explanation is that it may be due to the use of pre-test.

In this study, Pre-test and Post-test were conducted. Hence this threat was eliminated.
**Instrumentation**

The way in which instruments are used may also constitute a threat to the internal validity. Instrument can create problems if the nature of the instrument is changed in some way or other. This is referred to "Instrument decay".

The same pattern of achievement throughout tests was administered throughout the study. Hence this threat was nullified.

**Mortality**

Though the subjects of a study are selected carefully, it is common to lose some of the progresses. For example some individuals may dropout of the study or absent themselves during the collection of data.

No student was absent or a dropout. So this threat was eliminated.

**4.7 Threats to external validity**

External validity refers to difficulties in generalizing the findings of experimental research, interaction effect of selection biases and the experimental treatment.

This refers to the effect of some selection factor of intact group interacting with the experimental treatment, that not be the case if the groups had been randomly formed.

The subjects were randomly selected from low and high achievers, computer, Maths and Biology students. So this threat was eliminated.

**Multiple treatment interference**

When the same subject receives two or more treatments, there may be a carry over effect between treatments such that the results cannot be generalized to a single treatment.
Only one treatment was given to each group throughout the study. Hence this threat was eliminated.

4.8 Sample of the study

The research was carried out using experimental design with pre- and post-tests. The Municipal Girls Higher secondary school, Tirunelveli town has 3300 students studying in Standards VI to XII. In XII standard, nearly 200 students are studying in Tamil medium and 100 students in English medium. Of them, 70 students were taken as the sample for the study. All the students selected for the present study were studying in English medium. The students who were selected divided into two groups. The quarterly examination physics subject marks in the school record are collected for two groups. The scores are analysed and shown in table 4.1.

<table>
<thead>
<tr>
<th>Table 4.1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Physics achievement scores in quarterly examination</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>Group 1</td>
</tr>
<tr>
<td>Group 2</td>
</tr>
</tbody>
</table>

The above table shows that there is no statistical difference between group1 and group2. The mean scores of two groups are almost equal. Randomly one group is assigned as control group (Group1 in this study) and another one is assigned as experimental group. (Group2 in this study)
Fig. 4.2
Location of the sample

Table 4.2
Distribution of the sample

<table>
<thead>
<tr>
<th>Group</th>
<th>Experimental group</th>
<th>Control group</th>
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<tbody>
<tr>
<td>Computer group</td>
<td>11</td>
<td>10</td>
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<tr>
<td>Maths group</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Science group</td>
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<tr>
<td>Total</td>
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<table>
<thead>
<tr>
<th>Achievement level</th>
<th>Low achievers</th>
<th>High achievers</th>
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<tr>
<td></td>
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<td>12</td>
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<tr>
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<table>
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<th>Locality</th>
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<tr>
<td></td>
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<td>24</td>
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<tr>
<td>Total</td>
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<tr>
<td></td>
<td>Hindu</td>
<td>Total</td>
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<td>--------</td>
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<td>Religion</td>
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<table>
<thead>
<tr>
<th></th>
<th>Illiterate</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
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<td>17</td>
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<table>
<thead>
<tr>
<th></th>
<th>Illiterate</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
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<table>
<thead>
<tr>
<th></th>
<th>Coolie</th>
<th>Total</th>
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</thead>
<tbody>
<tr>
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<table>
<thead>
<tr>
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<th>Home maker</th>
<th>Total</th>
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</thead>
<tbody>
<tr>
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<td></td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>35</td>
<td>35</td>
</tr>
</tbody>
</table>

The computer branch students are studying Maths, Physics, Chemistry and Computer science subjects. The Maths branch students are studying Maths, Physics, Chemistry and Biology subjects. The Science branch students are studying Physics, Chemistry, Botony and Zoology subjects.

Students who are residing in the Tirunelveli city corporation limit are treated as urban students and not residing within corporation limit and living in villages are treated as rural students.

Those students who have failed in physics (scored below 35 out of 100) in quarterly examination result in school record are treated as low achievers. Remaining students are treated as high achievers.
4.9 Assumptions of the study

- The present level of the student's achievement in learning Physics is low.
- The application of Metacognitive strategies helps them to have effective learning.
- The higher secondary students learning physics could be improved.
- The utilization of metacognitive strategies help the students to develop their learning physics.

4.10 Delimitations

- This investigation is restricted to Government Girls Hr. Sec School, Tirunelveli town.
- This investigation is confined to XII standard students.
- I chapter in the XII textbook alone is covered for experimental purpose.
- The study will be considered for 15 days.

4.11 Lesson transcripts for the experimental group

The investigator selected Electrostatics topic in XII standard textbook as the topic of the study. The topic is divided into 6 lesson topics. The six sequentially arranged learning topics are Frictional electricity, Electric field, Electric dipole, Electric potential, Gauss law and applications and dielectric and capacitance.

The objectives of the learning topics are as follows

Learning topic 1: Frictional electricity

- The two types of charges and charge conservation
- The force of attraction and repulsion between charges
- Superposition principle and continuous charge distribution.

Learning topic 2: Electric field
- Electric field strength
- Electric field due to a point charge
- Electric field due to system of charges
- Properties of electric lines of forces

Learning topic 3: Electric dipole
- Electric dipole moment
- Electric field due to a dipole at a point on its axial line
- Electric field due to a dipole at a point on the equatorial line.
- Electric dipole in a uniform field and potential energy

Learning topic 4: Electric Potential
- Relation between electric field and potential
- Electric potential at a point due to a point charge
- Electric potential at a point due to an electric dipole
- Electric potential energy

Learning topic 5: Gauss' law and its applications
- Electric flux and Gauss law
- Electric Field due to an infinite long straight charged wire
- Electric field due to an infinite charged plane sheet
- Electric field due to two parallel charged sheets

Learning topic 6: Dielectric and capacitance
- Electrostatic induction
- Capacitance of a parallel plate capacitor
- Dielectrics and polarization
- Capacitors in series and parallel
- Energy stored in a capacitor
### Table 4.3

**Metacognitive activities schedule in lesson transcript**

<table>
<thead>
<tr>
<th>Phases</th>
<th>Description of activities</th>
<th>Time (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase I</td>
<td>Instructions were given, how use metacognitive activities in learning physics. Before coming to class, students are required to read the topics that will be discussed.</td>
<td>5 min</td>
</tr>
<tr>
<td>Inquiry based learning</td>
<td>Teaching physics concepts – Lecture method using power point presentation</td>
<td>30 min</td>
</tr>
<tr>
<td>Phase II</td>
<td>The investigator conducted inquiry based learning by posing carefully drafted questions. The investigator formulated pivotal questions in advance. The students were asked to respond to these questions, which helped them to develop higher level of thinking and also draw conclusions. Additional questions were framed in terms of student responses. But pivotal questions planned in advance gave direction and thrust to the lesson and helped to accomplish the goal.</td>
<td>15 min</td>
</tr>
<tr>
<td>Co-operative learning</td>
<td>Students are divided into 5 groups each consisting of 7 members. Each of the groups was named as learning cells. Each learning cells have at least two low achievers. High achievers in the group were allotted a single frame and she had prepared the same and taught the peers in the learning cells. The teacher explained the content coming under each frame and thus gave an overall description of the lesson. In the next stage, the students having same frames were grouped together to discuss themselves. This was done to equalize their knowledge and understanding regarding that particular frame which they have to teach others. The student instructor teaches the allotted frame to his peer group members and the teacher supervises the study. Discussing a topic among peers and offering a solution by peers. In this method the investigator provides instructional support as students learn to do the task and then gradually shifts responsibility to the students. Here high ability and low ability students work together in groups to complete the work.</td>
<td>20 min</td>
</tr>
</tbody>
</table>
In doing physics problems, the teacher roams around the room to access how well the students are doing. When students are doing problems, they were guided to ask themselves the following questions towards comprehending their cognitive processes:

- What in my prior knowledge will help me with this particular task?
- In what direction do I want my thinking to take me?
- What should I do first?
- Why am I reading this selection?
- How much time do I have to complete the task?

Every student is asked to work on the problem together. Students participate with the investigator, sometimes making mistakes and having to rethink where they have been. When they are monitoring or maintaining the plan of actions they are guided to ask themselves the following questions:

- How am I doing?
- Am I on the right track?
- How should I proceed?
- What information is important to remember?
- Should I move in a different direction?
- Should I adjust the pace depending on the difficulty?
- What do I need to do if I don't understand?

After the problem is completed by the student, they are directed to evaluate the plan of action by asking themselves the following questions:

- How well did I do?
- Did my particular course of thinking produce more or less than I had expected?
- What could I have done differently?
- Do I need to go back through the task to fill in any "blanks" in my understanding?
- Monitor the progress of solution
- Check the solution after finish answering
- Check answer, equations and calculation steps.

<table>
<thead>
<tr>
<th>Phase III Problem based learning</th>
<th>20 min</th>
</tr>
</thead>
</table>

| Total duration | 90 min |
The lesson transcripts based on the metacognitive strategies will be designed based on the metacognitive strategies given by Dr.E.Ramganesh in the year 2003, 2007, 2008 and 2009. The metacognitive strategies in the present study are designed by investigator under his guidance.

It consists of three phases. Phase I is inquiry based learning, phase II is collaborative learning and phase III is problem based learning. The prepared lesson transcripts were shown in the experts in the field of physics and education and necessary modifications were done in the content. Sample lesson transcript for phase I, II and III in learning topic 1 i.e. Frictional electricity is given below.

Learning topic 1: Frictional electricity
Name of the teacher : S.Rajkumar Std : XII
Name of the school : M.G.HSS Date : 28/3/2009
Subject : Physics Duration : 90 minutes
Unit : Electrostatics

**Instructional Objectives**
The pupil should be able to
- Recall examples from everyday experience for the transmission or redistribution of charges by rubbing the materials.
- Recognizes the two types of charges and charge conservation
- Understands the force of attraction and repulsion between charges
- Understands relative permittivity.

**Teaching materials**
- PowerPoint presentation using LCD projector
- A computer animation of experimental verification of charge types
- Pictures related to the topic
- Chart showing the distribution of charges
Teaching the concepts of two kinds of charges, attraction and repulsion between charged bodies and classification of materials, basic properties of electric charge, coulomb law and relative permittivity – Lecture method using power point presentation (30 minutes)

Phase-I Inquiry based learning (15 minutes)

The following questions were framed to elicit the answers from the students based on their previous knowledge or what they know? Additional questions are also asked in discussions.

Concept (i) Two kinds of charges (3 minutes)

A glass rod is rubbed with a silk cloth acquires positive charge. An ebonite rod is rubbed with fur, it becomes negatively charged. Charging a rod by rubbing does not create electricity. It transfers the charges in the material.

Teacher: Who named charges positive and negative?
Student: Benjamin Franklin
Student: Why it is called static electricity?
Teacher: Because, the charges in a body do not move
Student: What is the unit of charge?
Teacher: Coulomb
Teacher: What are the two kinds of electric charges?
Student: Positive and negative charges

Concept (ii) Attraction and repulsion between charged bodies and classification of materials (3 minutes)

A charged glass rod is brought near another charged glass rod repel each other. A ebonite rod is brought near another charged glass rod attract each other. Bodies which allow the charge to pass through are called
conductors. Bodies which do not allow charges to pass through are called insulators.

Teacher: ……………… Charges repel.

Student: Like charges

Teacher: What type of charges attract

Student: Unlike charges

Teacher: Can you give the application of force between charge bodies?

Student: Ink-jet printer, photocopier and fly ash collection in chimneys.

Teacher: Bodies which allow the charges to pass through are called………

Student: Conductors

Teacher: Give examples of conductors?

Students: Metals; copper, aluminum, etc.

Teacher: Bodies which do not allow charges to pass through are called

Student: Insulators

Teacher: Give examples of insulators?

Student: Non-metals; glass, mica, ebonite, plastic, etc.

**Concept (iii) Basic properties of electric charge (3 minutes)**

Quantization of electric charge \( q = ne \). Where \( e \) is the charge carried by the electron. The total charge in an isolated system always remains constant. Charges can be transferred from one part of the system to another such that total charge always remains conserved. Total charge of a system is equal to the algebraic sum of charges located in the system.

Teacher: Can charges be created?

Student: No. Charges cannot be created.

Teacher: Can charges be destroyed?

Student: No. Charges cannot be destroyed.
Teacher: What is the magnitude of e?
Student: 1.6x10^{-19}C
Teacher: If two charges +2q, -5q are brought in contact, what is the total charge of the system?
Student: -3q.

Learning outcome:

Electric charge of any system is an integral multiple of least amount of charge (e). Electric charges can neither be created nor destroyed. The total electric charge of a system is equal to algebraic sum of electric charges located in the system.

**Concept (iv) Coulomb's law (3 minutes)**

The force of attraction or repulsion between two point charges is directly proportional to the product of the charges and inversely proportional to the square of the distance between them.

\[ F = \frac{1}{4\pi\varepsilon_0} \frac{q_1q_2}{r^2} \]

Teacher: The force between the two charges is directly proportional to …
Student: Product of charge
Teacher: The force between the two charges is inversely proportional to …
Student: Square of the distance between two charges
Teacher: What is the value of constant of proportionality?
Student: 9x10^{-9}
Teacher: What is the direction of force between two charges?
Student: Along the line joining two charges
Concept (v) Relative permittivity (3 minutes)

\[ \frac{F}{F_m} = \frac{\varepsilon}{\varepsilon_o} = \varepsilon_r \] is called the relative permittivity of the medium. \( F_m = \frac{F}{\varepsilon_r} \), the force between two point charges depends on the medium in which two charges are situated.

Teacher:

The ratio between the permittivity of a medium to the permittivity of free space is called

Student: Relative permittivity

Teacher: What is the dimension of permittivity?

Student: Dimensionless

Phase – II Cooperative learning (20 minutes)

The topic is divided into five frames. They are

Frame 1 Two kinds of charges
Frame 2 Attraction and repulsion between charged bodies
Frame 3 Basic properties of electric charges
Frame 4 Coulomb's law
Frame 5 Relative permittivity

Students are divided into 7 groups each consisting of 5 members. Each of the groups was named as learning cells. Member 4 and 5 of each learning cells should be low achievers. Students in the group were allotted a single frame as shown in the table.
### Table 4.3

**Co-operative learning frame allotment**

<table>
<thead>
<tr>
<th></th>
<th>Member 1</th>
<th>Member 2</th>
<th>Member 3</th>
<th>Member 4</th>
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<tbody>
<tr>
<td>Learning cell 1</td>
<td>Frame 1</td>
<td>Frame 2</td>
<td>Frame 3</td>
<td>Frame 4</td>
<td>Frame 5</td>
</tr>
<tr>
<td>Learning cell 2</td>
<td>Frame 2</td>
<td>Frame 3</td>
<td>Frame 4</td>
<td>Frame 5</td>
<td>Frame 1</td>
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<td>Frame 3</td>
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<td>Learning cell 4</td>
<td>Frame 4</td>
<td>Frame 5</td>
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<td>Learning cell 5</td>
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<td>Learning cell 6</td>
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<td>Learning cell 7</td>
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<td>Frame 3</td>
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<td>Frame 5</td>
<td>Frame 1</td>
</tr>
</tbody>
</table>

Members had prepared the frame in advance and gave a report of what they have learned in front of the class in not more than a few minutes. Other students were invited to ask questions. The teacher explained the content coming under each frame and thus gave an overall description of the lesson.

In the next stage, the students having same frames were grouped together to discuss themselves. For example member1 of learning cell1, member5 of learning cell2, member4 of learning cell3, member3 of learning cell4, member2 of learning cell5, member1 of learning cell6 and member5 of learning cell7 are having frame1 are grouped together to discuss themselves. Similarly frame2, frame3, frame 4 and frame5 members are grouped. This was done to equalize their knowledge and understanding regarding that particular frame which they have to teach others. The student instructor teaches the allotted frame to his peer group.
members and the teacher supervises the study. Discussing a topic among peers and offering a solution by peers. In this method the investigator provides instructional support as students learn to do the task and then gradually shifts responsibility to the students. Here high ability and low ability students work together in groups to complete the task.

**Phase – III Problem based learning (20 minutes)**

**Problem 1**

The electrostatic force between two point charges kept at a distance $d$ apart a medium $\varepsilon_r = 6$, is 0.3 N. The force between them at the same separation in vacuum is?

*(Always ask questions to herself to stay focus to the problem.)*

Students identified the concept of coulomb's law that relates the force between two charges. Based on the knowledge student write the equation

$$F' = \frac{1}{4\pi\varepsilon_0} \frac{q_1q_2}{r^2}$$

Students are expected to list the given data. The data for the variable $q_1$, $q_2$ and $r$ are not found in the problem.

*(Read and reread the problem for better understanding)*

Students are guided to recall their previous knowledge of force in medium and force in vacuum.

*(Try more than one way)*

Write the coulomb equation in air and medium

$$F_{air} = \frac{1}{4\pi\varepsilon_0} \frac{q_1q_2}{r^2} \hspace{1cm} (1)$$

$$F_{medium} = \frac{1}{4\pi\varepsilon} \frac{q_1q_2}{r^2} \hspace{1cm} (2)$$
Now students are made to regulate of their own thinking to complete the task.

What is asked to find out?
How do you use the data?
\[ \varepsilon_r = 6 \]
\[ F_{\text{medium}} = 0.3 \text{ N} \]
\[ F_{\text{vacuum}} = ? \]

Students are made to understand what is known and unknown.

Dividing equation (1) by (2)

\[ \frac{F_{\text{air}}}{F_{\text{medium}}} = \frac{\varepsilon}{\varepsilon_0} = \varepsilon_r \]

Students are guided to check themselves in going in the right direction or not when each step is progressed.

\[ F_{\text{air}} = F_{\text{medium}} \times \varepsilon_r \]

\[ F = 0.3 \times 6 = 1.8 \]

*(Check answer, equations and calculation steps).*

Students are guided to judge of how well they can organize their previous knowledge in force between charges.

**Problem: 2**

Two small charged spheres repel each other with a force of \(2 \times 10^{-3}\) N. The charge on one sphere is twice that on the other. When one of the charges is moved 10 cm away from the other, the force is \(5 \times 10^{-4}\) N. Calculate the charges and the initial distance between them.

**Teacher asks what in your prior knowledge will help you in this particular task?**
By answering the question, students may possibly reach to a conclusion that the current task is regarding force between two charge spheres.

\[ F = \frac{1}{4\pi \varepsilon_0} \frac{q_1 q_2}{r^2} \]

**What are the differences/similarities between current task and those you solved earlier?**

Discussing with their peer group, students are likely to write the solution as follows

\[ Q_2 = 2q_1 \]

\[ 2 \times 10^{-3} = \frac{1}{4\pi \varepsilon_0} \frac{2q_1}{r^2} \quad \text{---------(1)} \]

Now students are made to regulate of their own thinking to complete the task.

\[ 5 \times 10^{-4} = \frac{1}{4\pi \varepsilon_0} \frac{2q_1^2}{(r + 0.1)^2} \quad \text{--------- (2)} \]

Dividing (1)/(2) gives

\[ \frac{20 \times 10^{-4}}{5 \times 10^{-4}} = \frac{(r + 0.1)^2}{r^2} \]

\[ 4r^2 = (r + 0.1)^2 \]

\[ r = 0.1 \text{m} \]

Substitute the value of \( r \) in equation (1)
\[2 \times 10^{-3} = 9 \times 10^9 \times \frac{2q_1^2}{(0.1)^2}\]

\[q_1 = 33.33 \times 10^{-9} \text{C} \quad q_2 = 66.66 \times 10^{-9} \text{C}\]

The control group was taught through the normal classroom lesson transcripts followed by teachers in the Conventional method. Students in the control group have the same sequence of lessons and the amount of time allotted was equal for both groups.

4.12 Construction and validation of tools

The investigator administered the following tools in this study.

- Achievement test in Physics
- Metacognitive awareness inventory
- Student attitude towards learning physics
- Home learning environment inventory
- Study habit inventory

4.12.1 Achievement test in physics

The investigator has gone through the XII standard Physics text book of TamilNadu Government. The first chapter of 12th standard text book was selected for this research. Major topics on the test were Electric fields, Electric dipole, Electric Potential, Gauss law and its applications, and Capacitance and Dielectrics. The questions were taken from the All India Engineering and Medical Entrance Exam question bank. There are 120 questions and all the questions are multiple choice questions. The questions were given to experts in Physics. Some questions are discarded and some are modified on the suggestions given by the experts. Samples
of 20 students in Government Hr. Sec. School, Kalakad are selected. The questions are given to the students and the answers are analysed as follows

**Item analysis**

It is the process of establishing the suitability of a question for inclusion in the final test. The quality of each item was ascertained by analyzing two important characteristics of the item namely (i) Difficulty index and (ii) Discriminating power.

The answer papers of the students are arranged in descending order of marks in the achievement test. The first 27% of the arranged cases are considered as upper group. The bottoms 27% of cases are considered as lower group. Then the responses given by the individuals for each item are tabulated, with the help of tabulated values the difficulty value and discrimination index are calculated as follows.

**Difficulty index**

\[ D = \frac{R_U + R_L}{N_U + N_L} \times 100 \]

- \( R_U \) – Number of students in the upper group who answered the item correctly.
- \( R_L \) – Number of students in the lower group who answered the item correctly.
- \( N_U \) – Number of students in the upper group
- \( N_L \) – Number of students in lower group

**Discrimination Value**

\[ V = \frac{R_U - R_L}{N_U (or) N_L} \]
The items are evaluated with the help of difficulty index and discrimination value. Items which are having difficulty index between 50 to 60 and discrimination value above 0.4 are retained and other items discarded. Seventy questions are selected and classified based on blueprint followed by Tamilnadu government public exam pattern covering knowledge, understanding, application and skill type questions.

**Blueprint**

The blueprint is a document that gives a complete picture of the test. It shows the distribution of questions and marks assigned for different objectives. It helps the test constructor to prepare appropriate questions to suit the purpose of test construction. Thus the blueprint was prepared showing the distribution of questions and scores for different objectives namely knowledge, understanding, application and skill.

**Table 4.5**

**Blueprint of the achievement test**

<table>
<thead>
<tr>
<th>No</th>
<th>Blue-print</th>
<th>Knowledge</th>
<th>Understanding</th>
<th>Application</th>
<th>Skill</th>
<th>Total questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Frictional electricity</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>2</td>
<td>Electric field</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>13</td>
</tr>
<tr>
<td>3</td>
<td>Electric dipole</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>4</td>
<td>Electric potential</td>
<td>2</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>5</td>
<td>Gauss law and its applications</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>6</td>
<td>Dielectric and capacitance</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td><strong>Total questions</strong></td>
<td><strong>16</strong></td>
<td><strong>18</strong></td>
<td><strong>22</strong></td>
<td><strong>19</strong></td>
<td><strong>75</strong></td>
</tr>
</tbody>
</table>
Table 4.6

Classification of questions based on achievement objectives

<table>
<thead>
<tr>
<th>Objectives</th>
<th>serial no. of the items in the achievement tool</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge</td>
<td>1-16</td>
</tr>
<tr>
<td>Understanding</td>
<td>17-34</td>
</tr>
<tr>
<td>Application</td>
<td>35-56</td>
</tr>
<tr>
<td>Skill</td>
<td>57-75</td>
</tr>
</tbody>
</table>

**Scoring**

The test paper was given to students and asked them to give tick mark against the best answer for each item. The sums of the rating against all the seventy five items of students are being observed. One score is assigned for each correct answer. Zero score is assigned for each wrong answer.

**Reliability of the achievement test**

In the present study, split half method was used for determining the reliability of the test. In this method the score obtained for each individual was divided into two groups by pooling the odd number items and even number items. The reliability was determined by using Product moment correlation formula. The obtained score is 0.87. This shows that the test has high reliability.
Validity of the achievement test

As far as achievement test is concerned, content validity and empirical or statistical validity is important.

Content validity

To ensure content validity the different sub units of the content were carefully examined and from each of the sub units, items were included. The content validity was established by the judgement of experts in physics test construction.

Construct validity

The construct validity of a test is the extent to which the test may be said to measure a "theoretical construct". For this the test items must be specific, concrete and precise. They must consist of definite limited tasks. The mental construct of the teacher who writes the test items determines the construct validity of the test. Tests should satisfy an analysis of effective expression. Mangal S.K.(2005) identified the following seven components for an analysis of effective expression (i) selection of ideas to be presented (ii) organization of ideas for presentation: (a) arrangement in logical (b) subordination of details to main ideas, (iii)paragraphing: use of paragraphs to bring out the organization of ideas, (iv) writing effective sentences; (v) effective use of words; (vi) adaptation to style to message: exposition, narration, etc., and (vii) adaptation to form to audience in style and word choice.

The investigator tried to follow almost all the above seven components in the present test. The topic selected was Electrostatics. The content was organized in a logical order. Adequate representation was given to sub concepts. The sentence styles varied in variety and length. Incomplete sentences were avoided and instead, sentences that convey a
single complete idea were incorporated. Selecting the precise meaning and variety made effective use of words. Narration in proper style with simple words constituted easily readable and comprehensible sentences. Thus the achievement test prepared by the investigator fulfilled the requirements for effective expression. Hence the test has good construct validity. The copy of the inventory is given in appendix A.

4.12.2 Metacognitive awareness inventory

In designing metacognitive awareness inventory, initially studies of metacognition and standardized instruments for assessing metacognition were reviewed (Schraw. G et.al (2004), Kleitman.S .et.al. (2007), Surya.A.et.al.(2008), Young.A.et.al (2008),Emri(2009)). First, domains of metacognitive skills were identified based on previous instruments. They are meta-knowledge, self-planning, self-monitoring, self-evaluation and self- regulation. In order to choose the best items in the previous instruments (Schraw.G & Denison R.S. (1994) and Kramarski.et.al (2004)) experts who are professors in B.Ed. College were asked to determine which items belonged to which domain and to what extent by rating the item 1 to 3. The mean rating for each question was calculated. The ones with the highest value were taken into consideration. Items were then reviewed for face validity. Wording and grammatical structures were improved according to Indian context and school student's level. The inventory after undergoing these processes ended up with 40 items in the form of statements true or false. It covers various aspects of metacognition in-depth and also be used to obtain scores for individual areas of metacognition as shown in following table.
Table 4.7

Classification of questions based on metacognitive awareness dimensions

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Dimension</th>
<th>Statement number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Meta-knowledge</td>
<td>4,9,11,13,14,15,17,25,36</td>
</tr>
<tr>
<td>2.</td>
<td>Self-planning</td>
<td>3,5,7,19,20,32,35</td>
</tr>
<tr>
<td>3.</td>
<td>Self-monitoring</td>
<td>1,2,10,18,22,26,39</td>
</tr>
<tr>
<td>4.</td>
<td>Self-evaluation</td>
<td>6,16,21,27,29</td>
</tr>
<tr>
<td>5.</td>
<td>Self-regulation</td>
<td>8,12,23,24,30,31,33,34,37,38,40</td>
</tr>
</tbody>
</table>

Scoring

The presence and absence of behaviour are marked in true or false. The score for the presence is '1' and the absence is '0'. The scale consists of 40 items in five dimensions. The total possible score of this questionnaire range from 0-40. The questionnaire helps to identify the presence of metacognitive behaviour among students.

Reliability and validity of the tool

The tool has been submitted to panel of experts in teachers in higher secondary schools. All the experts have agreed with the statement in the tool. Thus the content validity of the tool has been established. Cronbach α’s were 0.73, 0.78, 0.80, and 0.76 for meta-knowledge, self-planning, self-monitoring, self-evaluation and self-regulation respectively. We have applied the method test-retest in reliability study due to the scope and quality of the inventory. The inventory has been applied to 45 students two times at an eight weeks’ interval and the consistency between this resting results have been analyzed. The
correlation value between the two applications has been found to be 0.85. The copy of the inventory is given in appendix B.

4.12.3 Student attitude towards learning physics

Student attitude was designed based on the standardized tool of comolbo attitude survey questionnaire comprised 52 items.(Adams et.al.(2006)) It is used as a attitude tool by many researchers in Physics Education research.(Sawtelle.Vet.al.(2009), Mistades.ett.al.(2006)) According to Indian context and student level the investigator made necessary modifications under the guidance of the experts by rewording and reframing the sentences in the questionnaire. Some questions are discarded on the suggestion given by experts. Pilot study was conducted for a group 25 higher secondary students in Government higher secondary school, Kalakad.

Table 4.8
Results of pilot study of the attitude tool

<table>
<thead>
<tr>
<th>N</th>
<th>Number of items</th>
<th>Mean</th>
<th>S.D</th>
<th>K.R.20</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>35</td>
<td>110</td>
<td>11.8</td>
<td>0.80</td>
</tr>
</tbody>
</table>

From the above table the reliability (KR–20) of tool is 0.80, which is significant. Finally the questionnaire consists of 35 items in the form of statements strongly agree, agree, no option, disagree and strongly disagree.

Scores

20 of the items have positive meaning like “I enjoy solving physics problems" and the remaining have negative meaning like” I cannot learn physics if the teacher does not explain things well in class". Respondents
were instructed to mark their agreement or disagreement with the
decision on five point scales strongly agree, agree, no option, disagree
and strongly disagree. Responses were scored 5-1 from strongly agree to
strongly disagree for positive items and 1-5 from strongly disagree to
strongly agree for negative items. Hence maximum possible score range
from 35 to 175.

Reliability and validity of the tool

The tool has been submitted to a panel of experts of Professors in
College of Education and teacher's in higher secondary schools. All the
experts have agreed with the statement in the tool. Thus the content
validity of the tool has been established based on expert analysis and
judgment.

The investigator has used test-retest method for establishing reliability
of the tool. The investigator randomly chose 25 students in Government
Higher secondary school, Kalakad. The tool was given to them and
answer scripts are evaluated. After one month time, the same tool was
given to the same sample. The correlation coefficient was found for the
two sets of scores is 0.78. Thus, the reliability of the tool was found. The
copy of the inventory is given in appendix C.

4.12.4 Home learning environment inventory

The investigator used a home learning environment inventory
developed by Nair A.S. and Nirmaladevi(1981). It is used as a research
J.P (2007). This was intended to find out the extent to which the parents
and other significant members of the family provide facilities for the
attainment of maximum learning. It consists of 40 items covering
different aspects of home environment. The students are asked to respond to each item by putting a tick (\(\checkmark\)) against the entries of a three point scale marked "always", "sometime" and "never".

The weightage assigned as 3, 2 and 1 for the responses "always", "sometime" and "never" respectively for each item. The score of the individual is the sum of all scores obtained by him for all the 40 items in the inventory. The split-half reliability coefficient of the inventory was found to be 0.72. The validation of the tool was done by panel of experts in colleges of education. The copy of the inventory is given in appendix D.

4.12.5 Study habit inventory

The investigator use of Rao's study habit inventory constructed and standardized by Rao.G.D (1976). Agra psychological research cell publishes this tool. This tool is meant to access the study habit of higher secondary students. It is used as a research tool in the researches done by Joseph, C (1998) , Mathew T.K.(2003) and Hemalatha.P.K (2005). The inventory consists of 40 items of which 24 items are positive and 16 items are negative. Students were asked to mark their agreement or disagreement with the decision on five point scale always , most often , frequently , sometimes and never. Responses were scored 5-1 from most often to never for positive items and 1-5 from 1-5 from most often to never for negative items. Hence possible score range from 40 to 200.

Based on opinion of the experts in College of Education, necessary modifications had been carried out to finalize the tool. The validity of the tool was ascertained by content validity. The investigator established reliability by split-half method and it was found to be 0.84. The copy of the inventory is given in appendix E.
4.13. Experimentation

The time schedule for all the activities of the experimentation handling classes and administering tools was given in the form of the following table.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Day</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase I</td>
<td>Day 1</td>
<td>Motivation in physics learning</td>
</tr>
<tr>
<td>Phase –II (Pre-test)</td>
<td>Day 2</td>
<td>Conducted pre-test in Achievement test in Physics, Metacognitive awareness inventory, Student attitude towards learning physics, Home learning environment inventory and Study habit inventory</td>
</tr>
<tr>
<td>Phase-III Implementation of metacognitive strategies in lesson topics</td>
<td>Day 3</td>
<td>Topic 1: Frictional electricity Implementation of inquiry based learning</td>
</tr>
<tr>
<td></td>
<td>Day 4</td>
<td>Topic 1: Frictional electricity Implementation of cooperative learning Implementation of problem based learning</td>
</tr>
<tr>
<td></td>
<td>Day 5</td>
<td>Topic 2: Electric field Implementation of inquiry based learning</td>
</tr>
<tr>
<td></td>
<td>Day 6</td>
<td>Topic 2: Electric field Implementation of cooperative learning Implementation of problem based learning</td>
</tr>
<tr>
<td></td>
<td>Day 7</td>
<td>Topic 3: Electric dipole Implementation of inquiry based learning</td>
</tr>
<tr>
<td>Day</td>
<td>Topic</td>
<td>Learning Methods</td>
</tr>
<tr>
<td>-----------</td>
<td>-----------------------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------</td>
</tr>
<tr>
<td>Day 8</td>
<td>Topic 3: Electric dipole&lt;br&gt;Implementation of cooperative learning&lt;br&gt;Implementation of problem based learning</td>
<td></td>
</tr>
<tr>
<td>Day 9</td>
<td>Topic 4: Electric potential&lt;br&gt;Implementation of inquiry based learning</td>
<td></td>
</tr>
<tr>
<td>Day 10</td>
<td>Topic 4: Electric potential&lt;br&gt;Implementation of cooperative learning&lt;br&gt;Implementation of problem based learning</td>
<td></td>
</tr>
<tr>
<td>Day 11</td>
<td>Topic 5: Gauss law and its applications&lt;br&gt;Implementation of inquiry based learning</td>
<td></td>
</tr>
<tr>
<td>Day 12</td>
<td>Topic 5: Gauss law and its applications&lt;br&gt;Implementation of cooperative learning&lt;br&gt;Implementation of problem based learning</td>
<td></td>
</tr>
<tr>
<td>Day 13</td>
<td>Topic 6: Dielectric and capacitance&lt;br&gt;Implementation of inquiry based learning</td>
<td></td>
</tr>
<tr>
<td>Day 14</td>
<td>Topic 6: Dielectric and capacitance&lt;br&gt;Implementation of cooperative learning&lt;br&gt;Implementation of problem based learning</td>
<td></td>
</tr>
<tr>
<td><strong>Phase-IV</strong>&lt;br&gt;(Post-test)</td>
<td>Conducting post-test in&lt;br&gt;Achievement test in Physics&lt;br&gt;Metacognitive awareness inventory&lt;br&gt;Student attitude towards learning physics&lt;br&gt;Home learning environment inventory&lt;br&gt;Study habit inventory</td>
<td></td>
</tr>
</tbody>
</table>
4.14 Homogeneity of pre-test scores in the experimental group

The analysis of the pre-test scores of the experimental group and control group showed that no significant difference between two groups in achievement. The investigator selected intact classroom from different combinations of subjects (Computer, Maths and Science group), localities (urban and rural) and religion (Hindu, Muslim and Christian) to form two groups namely experimental and control groups. It is difficult to ascertain whether the difference between the pre-test and post-test scores resulted from the treatment factor or other variables. So it become necessary that the scores be analyzed using the technique of Analysis of Covariance (ANCOVA).

Analysis of covariance uses the principles of partial correlation with analysis of variance. It is particularly appropriate when the subjects in two or more groups are found to differ on the pre-test. In this case the effects of pre-test are partialled out and the resulting means of the posttest scores are compared. Analysis of covariance is a method of analysis enables the researcher to equate the pre-experimental status of the group items. Differences in the initial status of the groups can be removed statistically so that they can be compared through their initial status had been equated.

The homogeneity of the pretest scores are analyzed by ANCOVA. The results of the analysis are presented as shown below.
Table 4.10

Analysis of covariance (ANCOVA) of the achievement pre-test scores in the experimental group

From the above table obtained F value is 2.47, which is less than the table F value at 1% level of significance. This shows that there is no significant covariance in the pre-test scores in achievement. Hence the sample is homogeneous in pre-test.

4.15 Statistical tool used

For analyzing the collected data, following statistical techniques were adopted

- Descriptive analysis provides information about the nature of a particular group of individuals. They are mean, median, standard deviation, quartile deviation, skewness and kurtosis
- t-test to test the significance of difference between two means
- Paired 't' test to analyse the results from pre-test to post-test
- Effect size is a statistic that indicates the relative magnitude of the difference between two means.
- Omega Square is an index of the degree to which one variable accounts for another variable. It is a statistical index of the degree
to which the independent variable accounts for variance in the
dependent variable.
- ANOVA - Analysis of variance has been used to find out the
difference among the groups
- ANCOVA - Analysis of covariance is a method of analysis enables
the researcher to equate the pre-experimental status of the group
items.
- Chi-square test to find out the association between variables
- Pearson's moment correlation to find the relationship between two
variables.
- Multiple regression analysis to find out the relationship between
the achievement of the experimental group with intervening
variables metacognitive awareness, attitude towards learning
physics, Home learning environment and study habits.

The formulas for the above statistical methods are given in
appendix F.

4.16 Conclusion

In this chapter, the investigator discussed the method
selected for the study, research design, experimental design, variables,
sample of the study, assumptions and delimitations, sample lesson
transcript for the topic fictional electricity, construction and validation of
tools, experimentation schedule and statistical techniques used. In the
next chapter the statistical techniques used were dealt with suitable	
tabular columns and appropriate illustrations.