Chapter III

METHODOLOGY
### CHAPTER III

**METHODOLOGY**

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CHAPTER III

METHODOLOGY

3.1 OVERVIEW

The chapter gives an overall idea of the methodology followed by the investigator in conducting this study. It deals with the:

- Population and Sample of the Study
- Variables of the study
- Justification of the sample and Sampling Technique
- Experimental Design of the Study and
- Construction and Validation of the tools.

3.2 POPULATION OF THE STUDY

Population refers to the “aggregate or totality of objects or individuals regarding which inferences are to be made in a sampling study” (Sidhu, Kulbir Singh, 1992). A population is any group of individuals that have one or more characteristics in common that are of interest to the researcher (Ross, K.N. 1990). It therefore means all those people or documents, etc. who are proposed to be covered under the scheme of study. Kempthrone (1961) identified this as the target population and referred to the population of subjects that is available to the researcher for the study as ‘experimentally accessible population’. The target population of the present study is taken under three categories:
3.2.1 POPULATION FOR PHASE I - DIFFICULT CONCEPT IDENTIFICATION AND PHASE III – ORIENTATION PROGRAMME

TARGET POPULATION


EXPERIMENTALLY ACCESSIBLE POPULATION

This refers to all teachers recruited to handle standard IX in the 29 Government High Schools, 22 Government Higher Secondary Schools, 42 Aided High Schools and 63 Aided Higher Secondary Schools of Tuticorin Educational District (which comprises schools of Tuticorin and Koilpatti Districts) during 1997 - 1998.

3.2.2 POPULATION FOR PHASE II – ADMINISTERING DIAGNOSTIC TEST

TARGET POPULATION

This refers to all students enrolled in standard IX of all Government and Aided, High and Higher Secondary Schools of Tamilnadu during 1997 - 1998.

EXPERIMENTALLY ACCESSIBLE POPULATION

This refers to all students enrolled in standard IX in the 29 Government High Schools, 22 Government Higher Secondary Schools, 42 Aided High Schools and 63 Aided Higher Secondary Schools of Tuticorin Educational District (which comprises schools of Tuticorin and Koilpatti Districts) during 1997 - 1998.
3.2.3 POPULATION FOR PHASE IV – TO STUDY THE IMPACT OF REMEDIAL TEACHING LEARNING MATERIAL

TARGET POPULATION

This refers to all students enrolled in standard IX of all Government and Aided, High and Higher Secondary Schools of Tamilnadu during 1998 - 1999.

EXPERIMENTALLY ACCESSIBLE POPULATION

This refers to all students enrolled in standard IX in the 29 Government High Schools, 22 Government Higher Secondary Schools, 42 Aided High Schools and 63 Aided Higher Secondary Schools of Tuticorin Educational District (which comprises schools of Tuticorin and Koilpatti Districts) during 1998 - 1999.

3.3 SAMPLE OF THE STUDY

Sample refers to the subset of a population. Sample is a means by which units are taken from a population in such a way as to represent the characteristics of interest in that population. (Sidhu, 1992). Based on the calculations of sample size estimate for a finite population, the selected sample size are as follows:

3.3.1 SAMPLE FOR PHASE I - DIFFICULT CONCEPT IDENTIFICATION

The variables chosen for Phase 1 are the nature of schools – Government and Aided Schools. 24 Government Schools and 49 Aided Schools were selected. To justify the estimated sample size, more than one teacher was made to represent few Government and Aided Schools. Hence, 33 Government School teachers and 69 Aided Schools teachers were selected as the sample to identify the difficult science concepts as perceived by them.
3.3.2 SAMPLE FOR PHASE II – ADMINISTERING DIAGNOSTIC TEST

The variables chosen for Phase II are the nature of schools – Government and Aided Schools and the nature of students – Boys and Girls. 300 Government School Boys, 225 Government School Girls, 620 Aided School Boys and 360 Aided School Girls were selected as the sample.

3.3.3 SAMPLE FOR PHASE III – ORIENTATION PROGRAMME

The orientation programme aimed to provide teachers with the remedial teaching learning material developed by the investigator. Hence 15% of the total population was chosen as the sample for this study. 7 Government School teachers and 15 Aided School teachers were selected as the sample for this phase.

3.3.4 SAMPLE FOR PHASE V – IMPACT OF REMEDIAL TEACHING LEARNING MATERIAL

The experimental group refers to those schools, in which the teachers who attended the orientation programme taught science to students using the remedial teaching learning material. An equivalent group of students were selected as the sample for the control group from schools which did not use the RTLM kit. 90 boys and 50 Girls from government schools and 180 boys and 120 girls from aided schools were selected as the sample for the experimental group. 90 boys and 50 Girls from government schools and 160 boys and 140 girls from aided schools were selected as the sample for the control group.

3.4 SAMPLING STRATEGY

Cochran, G. William (1977)\(^6\) explained a ‘Stratified Random Sampling’, also sometimes called proportional or quota random sampling which involves dividing the population into homogeneous subgroups and then taking a simple random sample in each subgroup. The
procedure is to divide the population into non-overlapping groups (i.e., *strata*) \( N_1, N_2, N_3 \ldots N_i \), such that \( N_1 + N_2 + N_3 + \ldots + N_i = N \) and then do a simple random sample of \( f = n/N \) in each stratum. Stratification of the sample and justification as to how it represents the experimentally accessible population is given in table 3.1

### TABLE 3.1

**STRATIFIED RANDOM SAMPLING**

**JUSTIFICATION OF THE SAMPLE**

<table>
<thead>
<tr>
<th>Stage of the Study</th>
<th>Details</th>
<th>Variables</th>
<th>Government Schools</th>
<th>Aided Schools</th>
<th>Total</th>
<th>% of EAP</th>
<th>% of SSS in EAP</th>
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<tbody>
<tr>
<td>Stage I - Diff. Concept Identification I</td>
<td>Experimentally Accessible Population (EAP)</td>
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<td>Boys (EAP-1 &amp; SSS-1)</td>
<td>Girls (EAP-1 &amp; SSS-1)</td>
<td>% in EAP-1 &amp; SSS-1</td>
<td>% in EAP-2 &amp; SSS-2</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Selected Sample Size (SSS)</td>
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<tr>
<td>Stage II - Diff. Concept Identification II</td>
<td>Experimentally Accessible Population (EAP)</td>
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<td>Girls (EAP-1 &amp; SSS-1)</td>
<td>% in EAP-1 &amp; SSS-1</td>
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<td>Selected Sample Size (SSS)</td>
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<td>Girls (EAP-1 &amp; SSS-1)</td>
<td>% in EAP-1 &amp; SSS-1</td>
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<td>Selected Sample Size (SSS)</td>
</tr>
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<td>Stage IV - Impact of Remedial Teaching Learning Material</td>
<td>Experimentally Accessible Population (EAP)</td>
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<td>Girls (EAP-1 &amp; SSS-1)</td>
<td>% in EAP-1 &amp; SSS-1</td>
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<td></td>
<td>Control Group - Selected Sample Size (SSS)</td>
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</table>
3.5 VARIABLES OF THE STUDY

Variables are the conditions or characteristics that the experimenter manipulates, controls or observes. The *independent variables* are the conditions or characteristics that the experimenter manipulates in his or her attempt to ascertain the relationship to the observed phenomenon. The *dependent variables* are the conditions or characteristics that appear, disappear or change as the experimenter introduces, removes or changes the variable. The present study includes different phases and the independent and dependent variables in each of the phase is given in table 3.2
# TABLE 3.2
VARIABLES USED IN THE STUDY

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<thead>
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<th>Sl.No.</th>
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<td>Difficult Concept Analysis</td>
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<td>The opinion teachers on the extent of difficulty</td>
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<td>Nature of schools</td>
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<td>2</td>
<td>The nature of difficulty analysed through open ended responses</td>
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<td>Locality of schools</td>
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<td>Sex of the teachers</td>
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<td>Qualification of the teachers</td>
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<td>Phase 2</td>
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<td>Nature of schools</td>
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<td>Sex of student sample</td>
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<td></td>
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<td>6</td>
<td>The community of students</td>
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<td>The opinion of teachers on Entry Exit behaviour Analysis Opinionaire</td>
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<td>Nature of schools</td>
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<td>Sex of student sample</td>
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<td>Achievement of Experimental and Control Group students in achievement test.</td>
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<td>Nature of schools</td>
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<td>Community of students</td>
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3.6 RATIONALE FOR THE DESIGN OF THE STUDY

This study is primarily exploratory and experimental in nature. As the first step, the investigation is designed to gather information from teachers and students on the nature of difficulty they feel while teaching and learning the Science concepts respectively. Then, it further designed remedial teaching learning material to help the teacher and the student overcome the difficulty. The selected sample of teachers was then oriented in the use of the materials and the impact of the remedial teaching learning material on teaching and learning science concepts was studied. This mixed-method research design used a blend of different methods of research to capture a more complete, holistic and contextual portrayal of the phenomenon under study.

The strength of a mixed-method, or "multi-instrument approach" (Pelto and Pelto, 1978)\(^7\) to educational and psychological research, lies in its "triangulation" of multiple sources of data (Jaeger, 1988)\(^8\). Lincoln and Guba (1985)\(^9\) discuss several advantages, which are realized from using a combination of different methodologies. William Trochim (2000)\(^10\) makes the point that some methods are more quantitative (e.g. surveys, automated counting). However there can be qualitative surveys - using open-ended questions.

The quantitative approaches produce quantifiable, reliable data that are usually generalizable to some larger population. To get information on the quantifiable number of the sample on their opinion on the nature of difficulty the response survey items were used. To make this data qualitative by knowing the meaning the respondents assign to the nature of difficulty, open ended response items were also included. This study therefore uses quantitative methodologies (selected-response survey items and achievement test items) in conjunction with qualitative methodology (open-ended survey response items). The advantage of using both the methods generates rich and detailed data that leave the participants' perspectives intact and
provides a context for the nature of difficulty in terms of teaching and learning the science concepts. The data collected in this phase of the study helped in designing the remedial teaching learning material and its impact on teaching and learning the science concepts was studied through experimental method. "Experimentation consists in the deliberate and controlled modification of the conditions determining an event, and in the observation and interpretation of the changes that occur in the event itself" (Sidhu, 1992). The different research methods and tools were combined to give added dimensions to the findings. The data collection work sharply focused on the major objectives of the study.

3.7 DESIGN OF THE STUDY

The study was conducted in five phases. The study is a multi-instrument approach with a combination of survey and experimental research.

3.7.1 PHASE 1: DIFFICULT CONCEPT ANALYSIS

The main objective of this phase was to identify the difficult concepts in science from teachers’ perspective. The term teachers’ perspective is used because the difficult science concepts as identified by the teachers were difficult in the following dimensions:

- Difficulty faced in teaching science because of various intervening variables such as lack of adequate infrastructure, lack of adequate information in the text book, different subject background of the teacher – for example a teacher specialized in Botany might find it difficult to handle a Physics concept and influence of other demographic variables such as experience of teacher, locality of school, medium of instruction and the nature of school in teaching the concept.

- Difficulty faced in learning science: The experience of the teacher made the teacher perceive certain concepts as difficult by understanding the nature of the student, how
they process information and the performance of the students in comprehending particular concepts.

Tool 1 - Difficult Concept Analysis Opinionnaire was administered to collect data on the opinion of teachers on the extent and the nature of difficulty of the science concepts. The tool used in Phase 1 is an opinionnaire – a survey instrument used to collect information on what the person says on certain aspects of the issue under consideration.

The tool measures quantitative and qualitative data. Quantitative data is measured in the form of the number of teachers choosing a particular concept as 'high', 'moderate' or 'easy'. The data collected revealed the extent of difficulty. Qualitative data is assessed in the form of open ended responses. If a concept is stated as difficult, the teachers were asked to write their opinion on why the concept is difficult. The data collected revealed the nature of difficulty.

3.7.2 PHASE 2: ADMINISTERING DIAGNOSTIC TEST

This phase of the study had the primary objective of analyzing the difficult concepts in science from learners' perspective. The tool used is a survey testing instrument – 'Diagnostic test'. The learning outcomes expected when a student attempts a question in the diagnostic test is given in the form of action verbs as tell, list, identify, write, cite, define, draw, state, associate, compare, compute, describe, differentiate, discuss, distinguish, explain, predict, solve, relate, illustrate, apply, calculate, illustrate, interpret, locate, infer and predict. The weightage to objectives was distributed on the various domains of learning - knowledge, comprehension, application, analysis and synthesis. The difficulty in comprehending the concept was analyzed in the form of action verbs. For example:

The student might find difficulty in

- recalling concepts due to intervention of a previously learnt concept.
- identify the units of a concept from the equation or from definition.
- solving problems and
- applying the concept learnt in practical situations

The action verbs gave a list of the nature of difficulties faced by the students in learning the concepts. The data collected provided information on the nature of difficulty faced by the students in learning the science concepts.

3.7.3 PHASE 3: PREPARATION OF REMEDIAL TEACHING LEARNING MATERIALS (RTLM)

Phase 3 was a preparatory stage. The extent and nature of difficulty in teaching and learning the science concepts as perceived by teachers and the nature of difficulty faced by the students in learning the science concepts were analysed. Remedial Teaching Learning Materials were prepared to help the teacher and the learner overcome the nature of difficulty identified. The RTLM was prepared in two phases:

- Phase 3a – which covered the topics to be dealt with in the first term of the academic year. (Till the month of September).
- Phase 3b – which covered the topics to be dealt with in the second term of the academic year. (From the month of October to March)

A sample of the procedure followed in developing the RTLM is explained below:

**Concept: Charles Law**

**Step 1:**

The nature of difficulty as perceived by teachers was first analysed: (This was obtained through the open ended responses given by the teachers).

a. Situations where Charles law can be applied and interpreted could be given as examples.

b. Real time examples are essential.

c. Simple activities are essential to explain the phenomenon.
d. Finds difficulty in relating volume and pressure change as temperature changes.

Step 2:

The nature of difficulty as perceived by students was then analysed: (This was obtained through the analysis of performance of students in the diagnostic tests).

a. Lack of proper understanding of the Charles law and fails to remember that Charles law talks about variation of temperature at constant pressure and volume.

b. Misinterprets the question to Boyles law formula "PV = Constant" and has tried to answer that since pressure is constant, volume is constant.

Step 3:

As the third step, the objectives of preparing the RTLM were framed:

To overcome teacher perspective difficulties, the teacher must be able to help students

1. Explain Charles Law
2. Observe and Interpret Situations where the gas laws are applied.
3. Apply the gas laws in real life examples
4. Solve problem situations of application of the two gas laws.
5. Demonstrate situations of applying gas laws.

To overcome learner perspective difficulties, at the end of the session, the students must be able to

1. Explain Charles Law.
2. Interpret situations where gas laws are applied.
4. Demonstrate activities where gas laws are applied.
5. Infer from real life situations how gas laws are applied.
Step 4:

Development of Remedial Teaching Learning Material to help the teacher and the learner overcome the difficulties of learning the science concepts.

(Refer Appendix A - RTLM User Manual – English and Tamil - Concept No.24)

Activity Session (L4.C24.AS1): CANDLE AND WATER
Activity Session (L4.C24.AS1): EXPANDING AND SHRINKING BOTTLE
Activity Session (L4.C24.AS1): A CAN OF AIR
Activity Session (L4.C24.AS1): SUCK AN EGG

The remedial teaching learning materials were designed to help the teachers and the learners overcome the difficulties mentioned and the objectives in the preparation of RTLM for the specific concept were fulfilled.

3.7.4 PHASE 4: ORIENTATION PROGRAMME

Phase 4 was a preparatory stage in which the teachers from selected schools were oriented in using the RTLM. It was also a screening stage because it helped the investigator get the feedback of teachers on the impact of RTLM.

In the preparatory stage, a sample of the teachers were selected to represent the population under study to orient teachers in using RTLM and to help the teacher and learner overcome the difficulty felt in learning the science concepts. A complete kit of RTLM was distributed to all teachers who attended the orientation programme. The orientation programme was conducted in two sessions (Phase 4a and Phase 4b) to give wide content coverage, to have a follow up of the impact of using RTLM in the class, to take adequate time in the careful preparation of RTLM and to produce it with every minute detail.

In the screening stage, feedback on the opinion of teachers on the effect of RTLM, as to whether it helped them overcome the difficulty was obtained.
3.7.5 PHASE 5: IMPACT OF RTLM

Phase 5 was the evaluation phase where the impact of RTLM was studied. This phase had a development stage of one academic year. The RTLM was provided to 153 science concepts and these concepts were scattered in the whole of the science text book of IX standard science. The regular curriculum of IX standard was not disturbed and as and when the teacher had to teach the difficult science concept, the teacher oriented in using the RTLM made use of the remedial material. At the end of the academic year, the impact of RTLM on the achievement of students was studied through a simple experimental design – “Two Group Post Test Only Experimental Design”. It consisted of the following:

- Random assignment individuals to two groups:
  (i) an experimental group receiving the intervention being studied and
  (ii) a control group not receiving the intervention.
- Obtain measures only once – after the intervention had occurred.
- Collection of post-test data from each group.

The experimental group consisted of students selected from the schools where the teachers used RTLM to teach the science concepts. The control group of students was matched in the other demographic variables such as nature of school, sex, locality of school and medium of instruction. The achievement test was conducted to both the groups to study the impact of RTLM in the achievement of students.

The phases of the study, procedure, tool used, sample chosen and the schedule of the study is summarized in table 3.3
**TABLE 3.3**

**PHASES OF THE STUDY**

<table>
<thead>
<tr>
<th>Objectives of the Study</th>
<th>Phase</th>
<th>Procedure</th>
<th>Tool Used</th>
<th>Sample</th>
<th>Schedule of the Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification of difficulties in learning Science</td>
<td>Phase 1</td>
<td>Difficult Concept Analysis</td>
<td>Difficult Concept Analysis Opinionnaire</td>
<td>102 teachers handling IX Standard Science</td>
<td>Month of February of academic year 1 of the study</td>
</tr>
<tr>
<td></td>
<td>Phase 2</td>
<td>Administering Diagnostic Test</td>
<td>Diagnostic Test</td>
<td>1505 students in IX standard</td>
<td>Month of March of academic year 1 of the study</td>
</tr>
<tr>
<td>Development, Orientation and Implementation of Remedial Teaching Material</td>
<td>Phase 3a</td>
<td>Orientation Programme I - Analysis of opinion of teachers of the effectiveness of the RTLM</td>
<td>Developing RTLM - For Stage 1 of Orientation Programme</td>
<td>22 teachers handling IX standard Science</td>
<td>Month of June of academic year 2 of the study</td>
</tr>
<tr>
<td></td>
<td>Phase 4a</td>
<td>Implementing RTLM in teaching and Learning Science</td>
<td>Entry Exit behaviour Analysis Opinionnaire</td>
<td>The students of 22 schools where the teachers oriented in using RTLM taught the difficult concepts using RTLM</td>
<td>First term of academic year 2 till September</td>
</tr>
<tr>
<td></td>
<td>Phase 3b</td>
<td>Developing RTLM - For Stage 2 of Orientation Programme</td>
<td>Remedial Teaching Learning Material</td>
<td>The students of 22 schools where the teachers oriented in using RTLM taught the difficult concepts using RTLM</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Phase 4b</td>
<td>Orientation Programme II</td>
<td>22 teachers handling IX standard Science</td>
<td></td>
<td>Month of September of academic year 2 of the study</td>
</tr>
<tr>
<td></td>
<td>Implementing RTLM in teaching and Learning Science</td>
<td>Entry Exit behaviour Analysis Opinionnaire</td>
<td>The students of 22 schools were the teachers oriented in using RTLM taught the difficult concepts using RTLM</td>
<td></td>
<td>Second term of academic year 2 (From September to March)</td>
</tr>
<tr>
<td>Evaluation of Remedial Teaching Learning Material</td>
<td>Phase 5</td>
<td>Administering Achievement Test</td>
<td>Experimental Group - 440 students selected from 22 schools where the teachers oriented in using RTLM taught science through RTLM</td>
<td></td>
<td>Month of March of academic year 2 of the study</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Achievement Test</td>
<td>Control Group - 440 students selected from 22 schools matched with the experimental group in terms of variables such as nature and locality of school, sex of students and medium of instruction.</td>
<td></td>
<td>Month of March of academic year 2 of the study</td>
</tr>
</tbody>
</table>
3.8 TOOLS OF THE STUDY

Selection and designing of tools is the most important part of a research. The following tools were used in this study.

3.8.1: TOOL 1: DIFFICULT CONCEPT ANALYSIS OPINIONNAIRE

“Opinion is what a person says on certain aspects of the issue under consideration. An opinionnaire is a special form of inquiry tool used by the educational researchers to collect the opinions of a sample population on certain facts or factors of the problem under investigation”. This survey instrument was designed as an exploratory tool to gather a large data of information on the extent of difficulty in teaching and learning the science concepts as perceived by teachers. As the first step the objectives of using the survey were framed as follows:

a. To identify the difficult concepts in science – the difficulty is in terms of teaching and learning the science concepts as perceived by the teachers.

b. To identify the extent of difficulty – very difficult or moderately difficult or easy.

c. To identify the nature of difficulty – if very difficult or moderately difficult, the opinion of teachers were collected on the nature of difficulty – both in terms of teaching and learning the science concepts. The responses were not limited to stated terms and the open statements of teachers on the nature of difficulty were collected.

To suit the above objectives, the tool construction was based on the following steps:

3.8.1.1 PRELIMINARY PROCESSING

Learning science effectively gives all pupils the opportunity to think and learn, and develop an interest and curiosity about the world around them through exploratory and investigative experiences and activities. (American Psychological Association, 1992; Pintrich, 1988) It has been well documented through research that the lack of science content
knowledge of high school teachers creates difficulties in both their teaching of, and attitude toward science. Appleton (1983; 1992)\textsuperscript{15, 16} and Skamp (1989; 1991)\textsuperscript{17, 18} in particular have conducted numerous and extensive studies exploring the relationship between teachers' science content knowledge, skills and abilities in teaching science, their attitudes toward science teaching and learning. The teacher's knowledge of the subject matter is considered as vital to pupils' opportunity to learn science. With this background, the preliminary processing of the tool aimed at identifying the areas, extent of difficulty and the nature of difficulty in teaching as well as learning the science concepts. This data collected aimed at the teachers' perspective on the concept.

The preliminary processing underwent the following stages:

2. Identifying the difficult concepts from all the concepts given in the science text book.
3. Selecting concepts with criteria based on teachers' perspectives.

The criterion for identifying the concept as difficult was broadly categorized as:

- Lack of background knowledge because of the varied disciplines the teachers come from. For example, a teacher specialized in Botany handling Physics concepts.
- Lack of adequate external resources to aid teaching of the concept. For example, lack of enough equipments, avoiding using any equipment that might 'go wrong'.
- Content Difficulties – in the form of inadequate explanation of the concept in the Science textbook, unclear figures and inadequate exercises given in the Science textbook.

The concepts were identified from all the disciplines of science as Physics, Chemistry, Botany and Zoology explained in the IX standard Science Text Book. The draft tool had 274 concepts. This preliminary processing identified 232 concepts.
3.8.1.2 CONSTRUCTION OF THE TOOl

A. ITEMS IN THE TOOL

The tool constructed was a multi-item scale with single-item measures were the individual items do not lead to a composite score. When a multi-item scale is used in a psychometric approach (Nunnally, 1978, Zeller and Carmines 1980, Thorndike 1982, Spector 1992) it starts with the basic idea of an underlying theoretical concept or construct which cannot be directly observed and for which a measure is required. The items then constructed will be indicators of the underlying concept. In this approach the format has several items which are intended to measure one underlying concept. Spector has put in these concepts as “constructs which exist more in the minds of the social scientists than in the minds of their subjects” (Spector, 1992). Unlike such a psychometric approach, in this study the items were not pooled to study some basic underlying theoretical concept. Hence the basic steps of pooling items for an underlying theoretical concept to construct a multi-item scale do not fit into this study. Rather, each of the 232 items in the preliminary survey are attitudinal, seeking the opinion of the respondents towards the extent of difficulty in teaching and learning the science concepts – an issue in which the respondents have a direct apprehension. The items are assumed to be of individual interest in their own right.

B. SCALING ITEMS

The scaling procedure followed was a ‘comparative unidimensional scaling’ in which the respondent was presented with three items at a time - very difficult, moderately difficult or easy and asked to select one to pool their opinion on the extent of difficulty of the concept.
C. OPEN ENDED RESPONSES

The tool also included open ended responses for every concept so that the respondents are provided the opportunity to respond to the concept in whatever way they see fit. Open-ended response categories are useful for gathering qualitative data. It allows the respondent to suggest a range of difficulties unknown to the investigator, generates rich details, key words and phrases, generates ideas for future closed-ended response options, gathers data to explain responses to closed-ended response options, promotes a positive feeling for the respondent, that the input is valuable, informs the investigator how respondents come to possess a particular point of view, makes apparent to the investigator the obvious shortcomings in the respondent's knowledge and gives a chance to educate the respondent on the cause for the extent of difficulty they feel in teaching and making students learn the science concept.

D. PILOT STUDY

The tool was set for a pilot study to a representative sample of the population under study. The pilot study sample was justified with the total sample size by selecting 4 (33%) teachers from Government Schools and 8 (67%) teachers from Aided Schools of the 12 (100%) schools selected as sample for the pilot study from Arumuganeri, Koilpatti, Mudivaithanenthal, Sawyerpuram, Kayalpattinam and Tuticorin.

E. ITEM ANALYSIS

Item analysis was done with a view of accepting or rejecting the items. The multi-item scale aimed at identifying the difficult concepts in teaching and learning science. Every single item in the scale measured different concepts. Hence a composite scoring was not given. The result of the tool was used to design the remedial teaching learning material. The Chi Square ($\chi^2$) test of hypothesis of normality was applied to analyze the extent of significant deviation.
between the opinions of teachers on the nature of difficulty of the concept. The final concepts were chosen on the following basis:

- If there is no significant deviation between the opinions of teachers on the nature of difficulty of the concept, it reveals that the teachers equally feel the concept as highly difficult, moderately difficult and easy to be dealt with in a science class. Hence, these concepts cannot be rejected as easy. It reveals the varied opinion of teachers and hence chosen for the final tool.

- If there is a significant deviation between the opinions of teachers on the nature of difficulty of the concept, the deviation is because of the high frequency distribution in any of the three natures of concept – hard, medium and easy. The high frequency distribution among which of these three natures of the concept has led to a significant deviation is identified.

- If the significant deviation is because of high frequency distribution in “easy”, the concept is considered to be easy to be taught and learnt in a science class by a majority of the teachers.

- If the significant deviation is because of high frequency distribution in “highly difficult” and “moderately difficult”, it reveals the opinion of teachers that the concept is moderately or highly difficult.

Hence of the 232 concepts in the pilot tool, 187 concepts were identified as those to be included in the final tool of the study.

F. VALIDITY

Validity is generally defined in terms of various types of evidence that a measuring instrument is indeed measuring what it purports to measure. The research methods literature generally distinguishes several different forms of validity – usually face, criterion, predictive and construct validity. In multi-item scales much emphasis is placed on the face validity of individual items and of the instrument as a whole. This is because:
Every individual item are seen as providing information about respondents’ opinions on particular issues in their own right and they are not just indicators of an underlying construct and

- The concepts to be measured are often the respondents’ own subjective conceptions rather than concepts which exist only in the minds of the investigator.

The appearance or reasonableness of the test is often referred to as face validity. The face validity of the ‘tool 1’ was assessed through expert opinion. Two experts were chosen for the following areas.

2. Research Experts – Experts in the field of research to validate the survey instrument as a whole.

Corrections suggested by the experts were included and the relevance of the survey items to the context of study was determined. As the survey instrument does not rely on an abstract concept embedded in the formal theory the survey items are taken to be of interest in the respondents own right.

G. RELIABILITY

Reliability can be defined as “the degree to which test scores for a group of test takers are consistent over repeated applications of a measurement procedure and hence are inferred to be dependable and repeatable for an individual test taker” (Berkowitz, Wolkowitz, Fitch, and Kopriva, 2000). Reliability is achieved when there is uniformity of measurement.

In the present study, the test-retest method was used to test the reliability of the tool. Test-retest reliability is estimated when the same test is administered to the same sample on two different occasions. This approach assumes that there is no substantial change in the construct being measured between the two occasions. The amount of time allowed between measures is critical. If the same thing is measured twice, then the correlation between the two observations will
depend in part by how much time elapses between the two measurement occasions. Since it is a tool with single item measures, no internal reliability estimate was possible. Consequently, the teacher sample of the pilot study was asked to complete the instrument a second time, four months after they had first completed it. The test-retest reliability estimate for the single-items ranged from .83 to .96, which indicates high correlation between the opinion and thereby the consistency of the tool.

H. SCORING PATTERN

The multi item scale with single item measures was not given individual scores. Rather the frequency of the teachers' opinion on the extent of difficulty of the concept was identified. The open ended responses of the teachers were also subject to statistical analysis.

3.8.1.3 ADMINISTRATION OF THE TOOL

The tool was administered to the selected sample of 102 teachers. The list of schools and the number of teachers chosen from each school is given in table C.3.1 of Appendix C.

3.8.2 TOOL 2: DIFFICULT CONCEPTS DIAGNOSTIC TEST

A diagnostic test can be defined as a "test used to diagnose, analyze or identify specific areas of weakness and strength; to determine the nature of weaknesses or deficiencies; diagnostic achievement tests are used to measure skills" (Delandshere, 1990). A diagnostic test serves two important purposes – it identifies students' strengths and weaknesses and provides more detailed coverage of skills and helps us mould our instructional program to address the weaknesses of our students. Main emphasis was also laid on measuring the intended learning outcomes defined as instructional objectives.
3.8.2.1: PRELIMINARY PROCESSING

The recent decades of education research have illuminated a rich collection of student difficulties in learning science and many cognitive theories have been developed to interpret them. These yield implications for assessment in the following general areas:

- Learning is affected by students’ previous knowledge. (Viennot 1979; Clement 1982; McDermott 1984)\textsuperscript{27,28,29}. Such knowledge often referred to as preconceptions, misconceptions, or alternative conceptions by educators, can have significant effects on students’ learning.

- Students can create new alternative ideas which can be different from both their previous knowledge and the community accepted scientific ones.

- Students’ knowledge structures can be different from that of experts in many ways. A deeper conceptual understanding is necessary for students to go beyond the surface details to succeed in transferring knowledge.

- There are commonly observed inconsistencies in students’ use of their knowledge in equivalent contexts. Maloney and Siegler (1993)\textsuperscript{30} suggested that a student might maintain several different understandings of a concept that would coexist and compete with, rather than replace, the student’s previous understandings. The understanding that wins the competition on a given problem will depend on an interaction between the understandings and the features of the problem.

- Inadequate infrastructure offers for certain concepts might lead to insufficient practice exercises and reduced understanding of the concepts.

With this background, the preliminary processing of the tool aimed at diagnosing the difficulties in learning the science concepts through the answers chosen in the diagnostic test.
The preliminary processing underwent the following stages:

1. Conducting informal interviews with students in IX standard and students who have completed standard IX.
2. Designing questions for the difficult concepts with distracting answers to diagnose the nature of difficulty.
3. Carefully selecting the learning outcomes measured by the test so that it reflects all the difficult concepts identified in the preliminary discussion with students.
4. Considering the knowledge, comprehension, application, analysis and synthesis domains in the design of the test.

3.8.2.2 DESIGNING THE TEST

The investigator created items for each difficult concept identified. The items used in the test were multiple choice items. The items were made clear and precise. It had a problem posed on the stem. Each item included one correct or most defensible answer. The diagnostic foils or distracters in each item could be clichés, common misinformation, logical misinterpretations, partial answers and technical terms or textbook jargons. The major purpose of this multiple-choice item was to identify the students who do not have complete command of the concept or principle involved. In order to accomplish this purpose, the foils or distracters were designed as to appear as reasonable as the correct answer to students who have not mastered the material. The options were then presented in a logical and systematic order. The options were made grammatically parallel and consistent with the stem. It was insured that correct responses are not consistently longer or shorter than the foils. Grammatical and verbal clues were eliminated. Negatively stated items were used only infrequently.

The preliminary draft was then presented to the experts for criticism and correction. Two experts were chosen for the following areas.

2. Research Experts – Experts in the field of research to validate the question construct.

They checked the coverage of the topic in the text, concise, unambiguous and grammatically correct items, relevance and logical ordering of the sequence of items in the test. Based on their suggestions, the investigator made corrections in the preliminary draft.

This preliminary processing identified 147 concepts and a total of 147 items were drafted.

A. PRE-PILOT STUDY

The tool was set for a pre-pilot study to a representative sample of the population under study. The pilot study sample was justified with the total sample size by selecting 90 (36%) students from Government Schools and 160 (64%) students from Aided Schools of the 250 (100%) students selected as sample for the pilot study. This sample also represented the schools already chosen for the pilot study of tool 1. The pre-pilot study sample represented the sample chosen for the study also in terms of other variables such as sex, nature of school, nature of locality and medium of instruction.

B. ITEM ANALYSIS

Item analysis is a process which examines student responses to individual test items (questions) in order to assess the quality of those items and of the test as a whole. Two important characteristics of each test item were tested.

1. Level of difficulty or item difficulty and

2. Discriminating power of the test items or item discrimination.

Item difficulty may be defined as the proportion of the examinees that marked the item correctly.\(^{31}\) In multiple choice tests, guessing plays an important role and boosts up the results of those who do not understand the item nor know its correct answer and hence indulges in guess work. Including the chance success, the formula for item difficulty is given as,\(^{32}\)

\[
P_e = \frac{R - \frac{W}{(k-1)}}{N-HR}
\]
Where

\[ P_e = \text{The percent of examinees who know the answer correctly.} \]
\[ R = \text{The number of examinees who get the correct answer.} \]
\[ W = \text{The number of examinees who chose the wrong answer.} \]
\[ N = \text{The number of examinees in the sample.} \]
\[ HR = \text{The number of examinees who do not reach the item and hence could not try solving it.} \]
\[ K = \text{Number of alternatives in the item.} \]

The answer scripts were subject to items analysis and the items with item difficulty index between .25 and .75 were chosen as the items for the final study.

C. ITEM DISCRIMINATION

Item discrimination refers to the ability of an item to differentiate among students on the basis of how well they know the material being tested. The procedure involves the following steps:

1. Identification of upper 28% (71) and bottom 28% (71) examinees. (Having highest and lowest scores in rank order respectively on the total scores.)
2. Calculating the percentage/proportion of the examinees attempting it correctly.
3. The discrimination index, DI was calculated by the formula:
   \[ DI = P_U - P_L \]
   in which,
   \[ DI = \text{discrimination index,} \]
   \[ P_U = \text{Proportion in the upper group passing the item,} \]
   \[ P_L = \text{Proportion in the lower group passing the item.} \]
4. Items having discrimination index above .20 are ordinarily regarded as satisfactory for use in most tests of academic achievement.33
The answer scripts were subject to items discrimination and the items with item discriminating index above .23 were chosen as the items for the final study.

This pre-pilot processing followed by item analysis and item discrimination helped the investigator draft 115 items for the tool 2 – Diagnostic Test (Refer: Appendix A). The test items included 44 (38%) concepts from Physics, 19 (17%) from Chemistry, 28 (24%) from Botany and 24 (21%) concepts from Zoology.

D. PILOT STUDY

The tool was set for a pilot study to an equivalent group of students chosen for the pre-pilot study. The schools chosen as sample for the pre-pilot study were also the sample for the pilot study. The number of students were also the same as the pre-pilot study. But a different group of students were chosen for the pilot study.

E. VALIDITY

Validity of a test or evaluation device can be defined as the degree to which the test measures what it is intended to measure. Content validity concerns, primarily, the adequacy with which the test items adequately and representatively sample the content area to be measured. Expert judgement (not statistics) is the primary method used to determine whether a test has content validity. The content validity of the diagnostic test was assessed on the basis of the judgements of experts who had examined the content of the test items and the question construct in the preliminary processing of the diagnostic test. The content validity was further judged in terms of adequacy of the instructional objectives and the test items in the diagnostic test.

F. RELIABILITY

The reliability of a test refers to the extent to which the test is likely to produce consistent scores. The reliability of the tool was established through split-half method. The split-half scores on the odd-numbered items were correlated with the scores on the even numbered items.
The obtained correlation coefficient was modified using Spearman Brown Prophecy formula for the full length test. The reliability coefficient estimated was .71 which indicates good correlation and thereby the consistency of the tool.

G. SCORING PROCEDURE

Each item in the diagnostic test carried 1 mark. There were 115 items and the maximum score which could be obtained by the student was 115.

H. PROBLEM OF GUESSING

Generally, it is stated that student’s scores on achievement test should be corrected for guessing. The guess work was to an extent avoided by warning the students that there will be deduction of marks for wrong answers.

Corrected Scoring Formula:

\[ \text{Score} = \text{Right} - \frac{\text{Wrong}}{n - 1} \]

where ‘n’ = number of alternatives in each item.

3.8.2.3 ADMINISTRATION OF THE TOOL

The tool was administered to the selected sample of 1505 students. The list of schools and the number of students chosen from each school is given in table C.3.2 of Appendix C. The percentage of students choosing each alternative and the correct answer was analyzed to study the nature of difficulty faced by the students.
3.8.3. TOOL 3: REMEDIAL TEACHING LEARNING MATERIALS (RTLM)

The term remedial instruction refers to "a course which tends or intends to rectify or improve the diagnosed difficulty". The difficulties analyzed were from both teacher and learner perspectives. The teachers' perspective analyzed the difficulty both in terms of the teacher and the student. The difficult concepts were identified and the nature of difficulty was carefully studied in the preparation of the remedial teaching learning material. The tools were termed as remedial teaching learning material because tools could be invariably used by the teacher to teach the concepts and by the learner to learn the concepts. The following criteria were also taken into consideration in the preparation of the RTLM:

- **Informing Intended Teacher Behaviour**
  
  To make teachers aware of what they are intended to teach in the form of guiding objectives of teaching.

- **Informing Performance Objectives**
  
  To spell out what students should learn across a particular session and ask students to monitor their efficacy in meeting the performance objectives. This should help them determine what they are intended to study.

- **Provide wide range of supplementary materials to help teaching and learning**
  
  A wide range of RTLM should be prepared to suit the need of the context, situation and the teachers should be oriented in the use of the material.

- **Emphasize concept relevance with everyday life applications**
  
  To build in suitable examples and analogies to explain each concept and relate new ideas to previously covered ones. "Students will be more motivated to self-regulate if they see the relevance," says VanZile-Tamsen (1999).35
- Model and encourage self-reflection through activity, brainstorming and problem solving sessions

Encourage and guide teachers to "Think out loud" when analyzing a theory or problem, so students will follow suit.

- Provide user manual for future reference

To aid the teacher in teaching using RTLM and guide students in learning using RTLM, the manual was provided which will also help the teacher as a good reference material.

- Prepare material in both medium of instructions – English and Tamil.

As the RTLM and its manual were to be used in classes which follow both medium of instructions, it was prepared in both mediums – English and Tamil.

With these underlying objectives, the RTLM had remedial methodologies and materials to suit the concept and the nature of difficulty as perceived by the teacher and the student. 153 concepts were identified as difficult and a comprehensive list of 302 RTLM was developed. The teaching learning methodologies used in the RTLM is given in table 3.4.

### TABLE 3.4

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Teaching Learning Methodology</th>
<th>No. of Sessions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lecture</td>
<td>106</td>
</tr>
<tr>
<td>2</td>
<td>Activity Session</td>
<td>80</td>
</tr>
<tr>
<td>3</td>
<td>Brain Storming Session</td>
<td>18</td>
</tr>
<tr>
<td>4</td>
<td>Lecture combined with Problem Solving Session</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>Problem Solving Session</td>
<td>13</td>
</tr>
</tbody>
</table>
The RTLM had remedial audio visual materials to suit the concept and the nature of
difficulty as perceived by the teacher and the student. The comprehensive list of the audio
visual materials used in the RTLM is given in table 3.5. These material were developed in both
the versions – English and Tamil to suit the medium of instruction.

TABLE 3.5
AUDIO VISUAL AIDS IN RTLM

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>AudioVisual Aid</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Poster</td>
<td>9</td>
</tr>
<tr>
<td>2</td>
<td>Picture Book</td>
<td>15</td>
</tr>
<tr>
<td>3</td>
<td>Analogy</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>Flash Card</td>
<td>69</td>
</tr>
<tr>
<td>6</td>
<td>Flash Card Set</td>
<td>26</td>
</tr>
<tr>
<td>7</td>
<td>Worksheet</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>Improvised Model</td>
<td>10</td>
</tr>
<tr>
<td>9</td>
<td>Suggested Improvised Aid</td>
<td>57</td>
</tr>
<tr>
<td>10</td>
<td>Suggested Improvised Aid and Flash Cards</td>
<td>4</td>
</tr>
<tr>
<td>11</td>
<td>Suggested Improvised Aid and Posters</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>Suggested Student Activity</td>
<td>4</td>
</tr>
</tbody>
</table>

3.8.3.1 TEACHING METHODOLOGIES

The teaching methodologies are used depending on the extent and nature of difficulty of the
science concepts.

A. LECTURE

Lecture can be defined as “a discourse on any subject; especially, a formal or methodical
discourse, intended for instruction; sometimes, a familiar discourse, in contrast with a
sermon.”36 The RTLM, though used the conventional lecture method as one among the teaching methodology, this lecture was supplemented by ‘Lecture Guides’. (Refer: Appendix A – RTLM Manual – English and Tamil). The lecture guides provided in the user manual of RTLM featured the following:

- The major ideas were highlighted
- Helped the teachers set the stage for forthcoming activities.
- Supplementary information was provided wherever needed.
- Guidelines on using the auxiliary audio visual aids were provided.

The lecture was also supplemented with audio visual aids depending on the extent and nature of difficulty of the concept.

B. ACTIVITY SESSION

An activity is something that is done. Learners learn by doing and also find interest and enjoyment in activity. During activity, the learners are given chance to explore and discover knowledge as they interact with a variety of materials provided to enhance their learning. The major purpose of activity methods is to enable the learner actively participate in their own learning. This participation enhances and sticks in the learner’s mind what is learnt. With the guidance of the teacher, the learner gets actively involved in the learning process as a participant, not a passive listener.

The RTLM had 80 activity sessions. The user manual featured the following information on activity sessions.

- Guidelines on how the session should be conducted.
- Learning outcomes of the session.
- Elicit the underlying principle of the concept through the help statements provided or leading questions given.
Materials are very important in activity methods. Students get actively involved in using different materials as they learn what is intended from them to learn by using the materials. The activity sessions were also provided with materials in the form of audio visual aids wherever needed.

C. BRAIN STORMING SESSION

Brainstorming is a conference technique by which a group attempts to find a solution for a specific problem by amassing all the ideas spontaneously by its members. Brainstorming is a process for generating new ideas. Brainstorming encourages and sparks off new ideas which would never have happened under normal circumstances. The RTLM used 18 Brainstorming sessions. These sessions characterized the following features:

- The user manual of RTLM helped the teachers to figure out how to solve the given problem situation.
- The sessions focused on two significant parts:
  (i) The creative process of the session – where the students were encouraged to give as many ideas as possible for the particular concept subjected for brainstorming.
  (ii) The critical evaluation process – where the group will discuss the ideas and choose the ones that seem to be most promising.
- The students were encouraged to build the ideas of others.
- The quantity of ideas was encouraged at the beginning of the session and it was narrowed down at a later stage.
- The judgment of ideas by the teacher was postponed to the end of the session.

Materials in the form of audio visual aids were also included in few sessions depending on the context, need and nature of difficulty.
D. PROBLEM SOLVING SESSION

A problem is a situation which is experienced by a learner as different from the situation which the learner ideally would like to be in. A problem is solved by a sequence of actions that reduce the difference between the initial situation and the goal. The RTLM used 13 Problem Solving sessions. These sessions had the following characteristic features:

- The learners are made to adhere to the following steps whenever a problem is presented to them. They will know a problem, identify possible solutions, test the decision and evaluate what has happened.

- There were different types of problem solving situations in the RTLM:

  (i) *Conversion Problems* - Conversion problems involve a given quantity and a target quantity that is directly equivalent. That is, the target quantity refers to the same thing or has a direct relationship. These are easily solved using a conversion factor.

  (ii) *Application of a Formula* - When a conversion problem involves one quantity related to one other, some problems involve a whole set of variables in some relationship. This relationship is expressed as a mathematical formula. In general the learner will be given values for all but one variable and asked for the unknown. The learner needs only to determine the formula and rearrange it algebraically so that the unknown is on one side of the equation and the given known are all on the other. Plugging in the known values will then help the learner get the answer.

  (iii) *Application of a Definition or Principle* - A definition or principle is a statement of relationship between things or concepts. Sometimes it can be stated mathematically as a formula or sometimes as words. The learners were guided to make sure that they understand the concepts or variables involved and what relationship was being stated.
(iv) *Transformations* - Transformations involve one or more elements that were transformed by an operation to give an answer. The operation works according to definite rules. For example in chemistry transformation problems were given in the form of chemical equations. Chemical equations represent the transformation of one substance into another according to rules inherent in their structure.

The problem solving sessions were suitably supplemented with audio visual materials as problem materials and in some instances to assist the learner in solving the problems.

**E. LECTURE COMBINED WITH PROBLEM SOLVING SESSION**

Integrating lecture with problem solving was used as a methodology in few sessions. These sessions gave a good deal of time and guidance for the students in solving the problems, identifying new problems and posing similar problems to the groups. The complexity of the problem was gradually increased as the lecture sessions went on. This also helps students in getting the relationships between the previous problems posed and the current problem. The RTLM had 4 such integrated sessions and these sessions were also supplemented with the audio visual materials.

**3.8.3.2: AUDIO VISUAL AIDS IN RTLM**

Audio visual aid are used by teachers, facilitators, tutors to help learners improve reading and other skills, illustrate or reinforce a skill, fact, or idea, provide concrete experiences, teach concepts which are difficult to be conveyed through speech only and motivate students and concentrate their attention on the teaching points.

*The RTLM included 199 audio visual aids* to serve as remedial tools for the teacher and the learner to overcome the difficulty in teaching and learning the science concept. (Refer: Table C.3.4 of Appendix C)
A. FLASH CARD

A flash card is part of a set of cards on which are written items or pictures related to the concept to be studied. The cards used in RTLM were good colour photographs, pictures, and written information. They were used to help students translate abstract ideas into realistic format, to provide visual examples, to simplify potentially complex topics by providing visual analogies, to provide students with still pictures of microscopic images to avoid misconceptions of the concept taught, to reinforce concepts which needed repeated exercises and practice and to brainstorm concepts to help students find the underlying principles of the concept.

B. POSTERS

The poster is a concise combination of word and image intended for easy and instant comprehension. The RTLM included 9 posters. Posters were prepared for those concepts which were felt by a majority of the teacher sample as though they are used mainly in class-room teaching, they can be left on the wall for future reference because of the significance of the topic. Posters were used in situations as to grab the attention of the audience through the punch lines. For example the poster developed for “Earth as a Magnet” made students clearly distinguish the magnetic north and south poles and the geographic north and south poles.

C. PICTURE BOOK

A picture book is a book that combines text (sometimes) and illustrations (always) to tell a story or convey a meaning. Picture books can tell a story or they may just focus on a concept. The RTLM included 15 such picture books. These picture books characterized the following features:

The picture books were primarily used for concepts which could not be explained by just few pictures but needed illustrative succinct explanations. They were designed in such a way
that it could also be used by learners as learning resources. They were used for illustrations to reinforce the concept, which could not have achieved otherwise due to inadequate explanations and illustrations in the regular text book.

D. ANALOGY

An analogy is basically a mapping mechanism, which helps a learner construct new knowledge on the basis of prior knowledge. They help us understand a new situation on the basis of a similar situation with which we are already familiar. The RTLM included 3 such analogies – where 2 are about the ultra structure of a cell – one being plants cell and the other animal cell. The other analogy was to explain the ‘law of definite proportions’. When analogies were used, the target concept was introduced, cues were provided for retrieval of analog concept, the relevant features between the target and the analog were identified and similarities were mapped and conclusions were drawn. Care was taken to make students be on track and do not get away from the main concept.

E. WORKSHEET

A worksheet allows us to enter, manipulate and verify data such as numbers and text. Worksheets are generally used for the purpose of exercise. The RTLM included one worksheet which was used in practice session to balance chemical equations.
F. IMPROVISED AIDS

The term improvisation means, "to make or provide something from available materials". If we say 'Science is Doing', teaching of every topic should possibly be supplemented by appropriate activities or practical. Sometimes the standard teaching aids may remain out of reach due to various reasons. An innovative teacher can prepare such an aid from the available materials from here and there. Improvisation is therefore, that which refers to an off-hand construction of a teaching aid with simple available materials costing little or nothing. The RTLM included 10 improvised models, which were provided as models as such to the sample teachers selected for the control group. These models, though improvised, involved simple construction and hence were provided by the investigator.

G. SUGGESTED IMPROVISED AID

Using locally available materials for constructing an aid not only involves low or no cost but also helps in reducing environmental hazard. These aids, are usually simple, easy to construct and easy to handle. RTLM also included improvised aids, which were not provided by the investigator but could be readily made from local resources. These aids for teaching and learning were termed as "Suggested Improvised Aids". The RTLM had 57 of such teaching aids. These aids are easily available and inexpensive materials in the environment.

H. SUGGESTED STUDENT ACTIVITY

Activity refers to "a set of actions through which inputs in the form of fun or games are mobilized to produce specific outputs in the form of understanding the underlying scientific phenomenon." Students while performing the activity also act as teaching aid in explaining the core concept. Such activities suggested to be used as aid in RTLM to overcome the difficulty in understanding the core concept were termed as 'Suggested Student Activity'.
The RTLM included 4 such activities. The activities were basically filled with fun but care was taken that it clearly resulted in developing the curiosity and creativity to comprehend the science concept which is the core of the activity. They were designed to make students active participants and give them hands-on experiences in understanding the concept.

1. FLASH CARD SET

‘Set’ refers to a series or collection of objects with basic commonality of its kind. Few concepts identified as difficult had a series of concepts to explain the basic concept. For example:

Concept: Allotropic Forms of Sulphur – where the explanation and comparison of structure is to be done for the various allotropic forms of Sulphur such as Rhombic, Monoclinic and Plastic Sulphur. The images being, clear photographs, flash cards were prepared separately for every allotropic form of sulphur.

Teaching aids of this kind was termed as ‘Flash Card Set’. The individual flash cards in the set are linked to teach the basic concept. Concepts which could not be taught through single pictorial representation were supplemented with this set. The different characteristic features of a concept were visually made available.

The RTLM included 26 of such Flash Card set with 103 individual flash cards.

3.8.3.3 WRITING USER MANUAL

The RTLM was supplemented with a complete user manual to guide the teacher on the procedures of using the RTLM. ‘Manual’ generally refers to a small reference book generally meant for the purpose of giving instruction on using a product. For every concept identified as difficult, the manual contained reference material. The manual designed had the following features.
- **Guide for Reading** – the primary objectives of how the teacher could help the students in using that particular part of the manual is listed.

- **Performance Objectives** – the specific learning outcomes of the learner on learning the specific concepts mentioned using the RTLM is listed.

- **RTLM** – comprehensive list of all the RTLM used for the specific concepts mentioned.

- **Teaching Guide** – The manual which explains
  - which RTLM in the form of audio visual aid should be used
  - which RTLM in the form of teaching methodology should be followed
  - how to use both – the tool and technique mentioned in RTLM.
  - how to lead the session using RTLM and
  - how to summarise the session.

The manual could be used by the teacher at any point of teaching for further reference on the techniques of teaching the difficult concept. The lecture guide for certain concepts served the purpose of additional reference. It served as a memory prompter to remind the teacher on the probing questions to be asked and lead the brain storming, activity and problem solving sessions. It was used as an extensive guide to the operations procedure of the models provided in RTLM.

**A. VALIDITY**

Content Validity is based on the extent to which a measurement reflects the specific intended domain of content (Carmines & Zeller, 1991).[^37] Content validity is usually established by **content experts**. The instrument was systematically judged by a panel of experts and rated as to the extent that the item adequately represents the need proposed. Six experts – two subject experts and two technical experts (the experts who did the preliminary processing of tool 1 and tool 2) were chosen to validate the RTLM. The other two were language experts who checked...
the language in the translated version of the RTLM. The following norms were taken into consideration while validating the tool.

- To develop RTLM for every concept identified as difficult.
- To analyse the nature of difficulty as perceived by the teacher and the student.
- To develop RTLM to suit the nature of difficulty.
- To analyse whether the RTLM developed could help the teacher and the learner overcome the difficulty perceived.
- To plan the construction of RTLM to suit the needs of both the teacher and learner.
- To design RTLM accordingly so that it could be used as a teaching and learning material.
- To design the user manual in a simple, precise way so that it could be used as a ready reference material.
- To make two versions of the RTLM so that the impact of using the RTLM could be empirically verified with teachers and students of English and Tamil medium schools.

B. RTLM REFERENCE

The images of audio visual aids used in RTLM (English and Tamil) and the user manual of RTLM (English and Tamil) are given in Appendix A.

3.8.3.3 ADMINISTRATION OF THE TOOL

The RTLM was administered in two phases:

1. The teachers from selected school were oriented on using the RTLM.
2. The teachers oriented in using the RTLM used the RTLM to teach science in their respective schools. The students learning science assisted with RTLM are then taken as the experimental group of the study.
The list of schools chosen as the sample for Orientation Programme is given in table C.3.3 of Appendix C.

The orientation programme was conducted in two sessions. The first session was held during the month of June – the beginning of the academic year and the second session was held during September when the teachers had their quarterly holidays. The teachers who did not attend the orientation programme conducted at the venue selected by the investigator were oriented in the use of the material at their respective schools by personal visits made by the investigator to those schools.

The teachers who were oriented in the use of RTLM, in turn used the RTLM to teach science in their respective schools. The students of these schools were selected as the experimental group to study the impact of RTLM on the achievement of students in learning science. 20 students were chosen from each school to represent the experimental group of the study. The total sample size was 440.

The difficult concepts identified were widely distributed in the whole of the science curriculum of IX standard and the administration of the tool was for the whole academic year till the teacher had completed the entire science syllabus for standard IX.

3.8.4 TOOL 4: ENTRY EXIT BEHAVIOUR OPINIONNAIRE

The multi-item scale with unidimensional single item measures constructed as tool 1 was utilized again with the following modifications:

- Tool 1 had a 3 point opinionnaire were the dimensions of scaling were termed as very difficult, moderate and easy. This tool was modified and the scaling dimensions were made two points – difficult and easy respectively. This was done to make the opinion of teachers more precise and clear.
Only the 151 concepts which were identified as difficult from teachers’ perspective were included in the tool.

As the orientation programme was conducted in two sessions, the tool was suitably modified and into two sections. Section A of the tool had concepts which were dealt with in orientation programme 1 and Section B had concepts which were dealt with Orientation Programme 2.

The entry behaviour of the teachers selected as sample for phase 3—orientation programme was already obtained during the participation of the same teachers as sample for tool 1. But since the tool was a 3 point scale, the procedure of combining columns explained by Marascuilo and Slaughter (1981) was followed. The scaling dimensions ‘very difficult’ and ‘moderate’ were combined and the tool was modified to have only two scaling points as ‘difficult’ and ‘easy’.

The selected sample of teachers was oriented in the use of RTLM. The orientation programme was conducted by subject experts so that the sessions could be made clearer and moreover the participants were also given opportunity to clarify their doubts to experts from the specific fields. Tool 4 was administered to the teachers to analyse their exit behaviour and thereby get their opinion on whether the RTLM helped them overcome the nature of difficulty in teaching and learning the science concepts as perceived by the teachers. The photographs of the orientation sessions are given in Appendix B.

3.8.4 TOOL 5: ACHIEVEMENT TEST

The diagnostic test constructed and validated as tool 2 was again utilized with the following modifications:

- The diagnostic test identified 63 concepts as difficult based on the performance of the students in the test. The nature of difficulty was analysed and the RTLM was designed
to help students overcome the difficulty. It was therefore considered that the impact of RTLM on the achievement of students could be well studied on analyzing the performance of students on those concepts which are identified as difficult. The achievement test therefore included only 63 concepts which were identified as difficult through phase 2 of the study. (Refer: Appendix A).

- The teachers selected for the orientation programme and who took part in phase 4 of the study was trained in using the RTLM. The schools in which these teachers work were chosen as the experimental group of the study. The students were selected in random based on the opinion of the teachers. 20 students were selected from each school selected as sample for phase 3 of the study.

- The control group for this phase of the study was the students who learnt the science concepts through the conventional method. A matched group 440 students from 22 schools were selected as the sample for the control group.

The list of schools selected as the sample for the experimental group is given in table C.3.3 of Appendix C. The list of schools selected as the sample for the control group is given in table C.3.5 of Appendix C.

The achievement test was conducted to the experimental and the control groups at the end of the academic year.

3.9 STATISTICAL TECHNIQUES EMPLOYED IN THE STUDY

Research data becomes meaningful in the process of being analyzed and interpreted. “Statistics” is an indispensable tool for any researcher to synthesize data and arrive at conclusions or decisions based on the interpretation of the results. In this study, the investigator has applied the following statistical techniques to analyze and interpret the data collected.
3.9.1: THE CHI-SQUARE TEST

Problems in social research frequently involve the counting of the number of persons, objects or responses as they occur under various categories of classifications. The data in such form of discrete categories and frequencies is compared using Chi square tests. The obtained set of frequencies in given categories is compared with a set of theoretical or expected frequencies. The chi square statistic is then used to measure the "divergence" of fact from hypothesis.

3.9.1.1 TEST OF HYPOTHESIS OF EQUAL PROBABILITY

These tests are used to analyze whether the frequency of opinions obtained indicates a trend significantly different from equal probability of opinions in each of the categories identified. The expected frequency is distributed equally in the given categories. The chi square value is computed using the formula:

\[ \chi^2 = \frac{\sum (f_o - f_e)^2}{f_e} \]

In which, \( f_o \) = Observed frequency in a single category.
\( f_e \) = Expected frequency.
\( \sum \) = Sum of

3.9.1.2 TEST OF HYPOTHESIS OF INDEPENDENCE (DIFFERENCE)

Chi square can be used to test whether two variables or attributes are independent or unrelated. Compute independent values or expected frequencies. This is found by multiplying the marginal totals common to a particular cell and then by dividing this product by the grand total of frequencies in the table. The chi square value is computed using the formula given in section 3.9.1.1.
3.9.1.3: CALCULATION OF CHI SQUARE FOR 2 X 2 TABLES

Yates' Correction for Continuity

Chi square is subject to considerable error in the following situations and requires the use of Yates' correction for continuity.

When working with 2 x 2 tables: Chi square is based on the assumption that adjacent frequencies are connected by a continuous and smooth curve (like the normal curve) and are not discrete numbers. In 2 x 2 tables this continuity of the curve is broken and needs a correction. A correction value of -.5 was applied and the chi square value is computed using the formula given in section 3.9.1.1.

3.9.1.4: SITUATIONS WHEN CHI SQUARE NORMS ARE VIOLATED

A. SAMPLING ZEROS AND STRUCTURAL ZEROS

As long as the frequency distribution in row category (i) and the column category (j) are both non-zero, the expected probability of falling into the corresponding cell (i,j) is also non-zero under the usual contingency table model of independence. If the total sample size is small, or if there are many cells in the table, then it may happen that no observations are recorded for a particular cell. These zero values in a table are sampling zeroes. However, the actual process that creates the observations may produce cells in the contingency table in which observations can never occur. The zero values that must occur in these cells are structural zeroes. A contingency table containing one or more structural zeroes is an incomplete table. The chi-square test and Fisher's exact test are not designed for contingency tables with structural zeroes. A more general logit or loglinear model will allow for the modeling of data that include structural zeroes.
B. SPECIAL PROBLEMS WITH SMALL OBSERVED CELL COUNTS FOR THE CHI-SQUARE TEST

SITUATION 1:

For tables with expected cell frequencies less than 5, the chi-square obtained may not be reliable. A standard (and conservative) rule of thumb is to avoid using the chi-square test for contingency tables with expected cell frequencies less than 1, or when more than 20% of the contingency table cells have expected cell frequencies less than 5.

SITUATION 2:

When no observations appear in a particular row category (row total is 0) or a particular column category (column total is 0), the chi-square statistic cannot be calculated. To proceed, the category must be either eliminated completely, or combined with another category.

When rows or columns are combined (collapsed together) to fix problems of small expected cell frequencies or zero-sum categories, care should be taken to do the collapsing such that the new hypothesis being tested is still of interest. If the null hypothesis of independence of row and column variables is true for all categories of each variable, then combining categories will preserve that property. However, collapsing can destroy evidence of non-independence, so a failure to reject the null hypothesis for the collapsed table does not rule out the possibility of non-independence in the original table.

3.9.2: PROCEDURE OF ANALYSIS OF NULL HYPOTHESIS 4.1B.1 TO 4.1B.6

Based on the norms explained in section 3.9.1.4, the analysis of analysis of null hypothesis 4.1B.1 to 4.1B.6 was done following the given procedure:
The observed frequencies of the opinions of teachers on the nature of the concept were entered on the basis of demographic variables.

A. SITUATION 1: SAMPLING AND STRUCTURAL ZERO’S

a. Cells with sampling zeros and structural zeros, in the column ‘easy’:

It is obvious that the concept is difficult. (Concepts rated as medium are also considered as those which require remedial teaching learning material and hence the columns are combined). Hence the log linear model is not applied for statistical analysis of the concepts with sampling and structural zeros. Further interpretation is made to identify to which category of people the concept is difficult.

b. Cells with sampling zeros and structural zeros, in the column ‘difficult’ and ‘moderate’:

The values of columns ‘difficult’ and ‘moderate’ are combined and the $\chi^2$ analysis was applied to find the significant deviation between the opinions of teachers belonging to different demographic variables on the nature of the concept.

This analysis leads to two situations:

(i) Significant Deviation: Indicates that there is a significant deviation between the opinions of the teachers (belonging to the specific category of demographic variable chosen) on the nature of the concept.

(ii) No Significant Deviation: Indicates that there is no significant deviation between the opinions of the teachers (belonging to the specific category of demographic variable chosen) on the nature of the concept.

B. SITUATION 2: CHI SQUARE ANALYSIS SHOWING SIGNIFICANT DEVIATION

As the columns rated as either ‘difficult’ or ‘medium’ are both considered as those which require remedial teaching learning material, when there is a significant difference, the concepts
are further analyzed by combining the values of 'difficult' and 'medium' to find out which cluster of distribution has led to the significant deviation.

a. **Significant deviation because of high frequency distribution in column 'easy':**

   It is interpreted that concept is rated as 'easy' irrespective of the demographic variable chosen.

b. **Significant deviation because of high frequency distribution in column 'difficult':**

   It is interpreted that concept is rated as 'difficult' irrespective of the demographic variable chosen. Further interpretation is made to identify to which category of people the concept is difficult.

C. SITUATION 3: CHI SQUARE ANALYSIS SHOWING NO SIGNIFICANT DEVIATION

When the $\chi^2$ analysis reveals that there is no significant difference, it indicates that the opinions of the teachers are widely distributed on the three columns, 'difficult', 'medium' and 'easy'. But a column wise total (total responses in 'difficult', 'medium' and 'easy') can alone reveal their opinion on the nature of the concept.

a. **Column wise analysis reveals no significant deviation:**

   If the column wise analysis has already revealed no significant difference in the analysis of primary hypothesis, it is understood that irrespective of the demographic variable chosen, the teachers have a mixed opinion on the nature of the concept – some feel it as 'easy' and some feel it as 'difficult'.

b. **Column wise analysis reveals significant deviation:**

   This analysis leads to two situations:

   (i) **Significant deviation because of high frequency distribution in column 'easy':**

      Irrespective of the nature of variable, the concept is widely accepted as 'easy'.

   (ii) **Significant deviation because of high frequency distribution in column 'difficult':**
Irrespective of the nature of variable, the concept is widely accepted as 'difficult'.

Further interpretation is made to identify to which category of people the concept is difficult.

3.9.3 PROCEDURE OF ANALYSIS OF NULL HYPOTHESES OF STAGE 2

The frequency of students who have answered the concept correctly and the frequency of responses in the distracting answers (which also includes attempted responses not attempted), attempted responses not attempted) was obtained. The Chi Square ($\chi^2$) test of hypothesis of equal probability was applied. The procedure of interpreting the values obtained is given below:

A. SITUATION 1: SIGNIFICANT DEVIATION BETWEEN THE FREQUENCY OF RESPONSES

When a significant deviation is observed, the next step is to identify the column which has the higher percentage of responses. ('Column 1' refers to the number of responses in 'Correct Answer' and 'Column 2' refers to the number of responses in 'Wrong answers').

a. Higher percentage of response in 'Correct Answer':

This indicates that a majority of the students has answered the concepts correctly. Hence these items are considered to be easy.

b. Higher percentage of response in 'Wrong Answer':

This indicates that a majority of the students has failed to comprehend the concept correctly. Hence it is obvious that these items are difficult. The reasons for choosing the distracting answers are further analyzed to interpret the nature of difficulty faced by the learner in comprehending the concept.
B. SITUATION 2: NO SIGNIFICANT DEVIATION BETWEEN THE FREQUENCY OF RESPONSES

This indicates that the students have equally chosen the correct and wrong responses. This also shows inadequate comprehending of the concept. Hence these concepts are also taken as 'difficult' concepts.

3.9.4: OPEN ENDED RESPONSE ANALYSIS

Mossholder, Settoon and Harris (1995)\(^42\) note that responses to open-ended questions are an under-utilized source of rich detail. They suggest that often data collected from open-ended responses are not intended for analysis but rather for developing other questions or reducing respondents' frustration by allowing them to explain their responses to other questionnaire items. Studies also often use excerpts from open ended responses to illustrate or emphasize quantitative findings. It is proposed that the actual analysis of open-ended questions and qualitative data in general is problematic. Hong (1984)\(^43\) suggests that much of the superiority of open-ended items in a questionnaire is usually lost when it comes to analysis, often resulting from lack of time and the large volume of data produced.

While the techniques for analyzing quantitative data are well documented and recognized, this is not so for the qualitative information produced by open-ended questions. Montgomery and Crittenden (1977)\(^44\) recommend an inductive approach to analyze open-ended questions, stating that it results in improved coding reliability. *Categories developed empirically from the responses to be coded will reflect the point of view of the respondents rather than just the point of view of the investigators if they had generated categories prior to coding.*
3.9.4.1: PROCEDURE OF ANALYSIS OF OPEN ENDED RESPONSE ANALYSIS

The open ended responses given by the teachers on the nature of difficulty is analyzed following the procedure given below:

1. Manual Method

   Each response was analyzed separately. Categories were developed from these responses. The categories were discussed and refined. New categories were then identified and listed.

2. Keyword Search

   The items from 5 selected filled in opinionnaires were keyed in to the 'survey analysis software' and the key words were identified. Cases were removed where there were duplicate responses and the context was inappropriate. The key words were hierarchically ordered into new categories or statements.

3. Computerization of new categories.

   The responses were analyzed again and were put in the newly identified categories based on the meaning they convey. The frequencies of occurrence of these responses were then analyzed.

3.9.5: MCNEMAR TEST

Researchers often employ dichotomous dependent variables in a pretest-posttest design to evaluate change or in a matched-pair design to assess the effectiveness of an intervention. Examples of common dichotomous variables of interest include yes-no attitude items and criterion-referenced measures or right-wrong items on a performance test. It should be noted that in situations where matching has been employed, comparing the proportions of "successful" instructed and uninstructed participants via a two-sample chi-square test of homogeneity is not statistically appropriate -- just as an independent samples t test would not be appropriate for assessing a difference in means between the two matched samples.45
Obviously correlated samples, such as a set of pre- and post-test observations on the same subjects, are not independent, and such data would be more appropriately tested by test like Cochran's Q test or McNemar's Q test.

With a single sample and a two-period study as an example, the data are typically arrayed in a $2 \times 2$ table in which one margin represents the two Time 1 categories, the other margin represents the two Time 2 categories, and the test of the hypothesis of equal marginal probabilities is conducted using the McNemar test.\(^{46}\) This McNemar test is an extremely simple way to test marginal homogeneity in $K \times K$ tables.\(^{47}\)

Statistical significance is determined by evaluating the probability of $\chi^2$ with reference to a table of cumulative probabilities of the chi-squared distribution or a comparable computer function.

**3.9.6 OTHER COMMON STATISTICAL TECHNIQUES EMPLOYED**

The other common statistical techniques used in the study are:

1. 't' Test for large uncorrelated samples.
2. One way ANOVA on hypothetical scores.
3. Post ANOVA test of difference by use of 't'.
REFERENCES


6. Ibid., pp.89-110.


23 Ibid. P.13.


32 Ibid., P.296.

33 Ibid., pp.297-298.

34 Ibid., P.290.


