CHAPTER 3
RESEARCH DESIGN AND METHODOLOGY

The present study was designed to study the effects of computer assisted instruction (CAI) on secondary school students’ attitude and achievement in Physical Science as compared to traditional teaching. The present research was a developmental cum experimental research. This study was conducted in two phases. During the first phase, development of tools and pilot study of multimedia CAI software were carried out, the detailed description of which is provided in chapter 4. In the second phase, effectiveness of the CAI software was checked. For checking its effectiveness, a randomized pretest-posttest control group design was implemented to determine any differences in their attitude and achievement. Pre- and post-intervention data were collected and analyzed using descriptive and inferential statistics.

In the present study, one of the quantitative research methods, namely, experimental research method was utilized to test the hypotheses proposed. Quantitative research approaches are applied in order to describe current conditions, investigate relationships, and study cause-effect phenomena. Studies that provide information about cause-effect outcomes are called experimental research. The experimental research is the only type of research that can test hypotheses to establish cause-effect relationships. True experimental research provides the strongest results of any of the quantitative research approaches because it provides clear evidence for the links between variables. As a result, it also offers generalizability, or applicability of findings to settings and contexts different from the one in which they were obtained. The steps in an experimental study are basically the same as in other types of research: selecting and defining a problem, selecting participants and measuring instruments, preparing a research plan, executing procedures, analyzing the data, and formulating conclusions. An experimental study is guided by at least one hypothesis that states an expected causal relationship between two variables. The experiment is conducted to confirm (support) or disconfirm (refute) the experimental hypothesis. In experimental research, the researcher manipulates at least one independent variable, controls other relevant extraneous variables, and observes the effect on one or more
dependent variables. He controls both the selection and assignment of the participants to groups. That is, he randomly selects participants from a well-defined population, then randomly divides them into two or more groups so that they have similar initial characteristics, and then randomly assigns these groups to different treatment conditions. He can also control the conditions in the research settings, such as when the treatments will be applied, by whom, for how long, and under what circumstances. After the groups have been exposed to the treatment for some period of time, the researcher collects data on the dependent variable from the groups and determines whether there is a significant difference between them. In other words, using statistical analysis, the researcher determines whether the treatment made a real difference. It is the ability to randomly select and randomly assigns participants to treatments that makes experimental research unique. The random assignment of participants to treatments, which is also called the researcher’s manipulation of the treatments, is the distinguishing aspect of experimental research (Gay, Mills, & Airasian, 2006).

In an experimental study, a researcher varies or manipulates an independent variable and assesses its effects on a dependent variable. A cause-and-effect relationship between an independent variable and a dependent variable is present when changes in the independent variable tend to cause changes in the dependent variable. The independent variable manipulated by the researcher in an experimental study is referred to as the experimental treatment or intervention. The independent variable, also called the causal, experimental, or treatment variable, is that treatment or characteristic believed to make a difference in dependent variable. The variable that is measured to determine the effects of the experimental treatment usually is referred to as the post-test, dependent variable, or criterion variable. If this variable is also measured before administering the experimental treatment, this measure is called a pre-test. The dependent variable, also called the criterion, effect, or post-test variable, is the outcome of the study, the change or difference in groups that occurs as a result of the independent variable. The dependent variable may be measured by a test or some quantitative measure. Thus, in an experimental study, researchers look at the effect(s) of at least one independent variable on one or more dependent variables.
Researchers in an experimental study try their best to control the effects of all the possible extraneous variables on the dependent variable as measured by a post-test. An extraneous variable is any variable other than the independent variable that, if not controlled, can affect the experimental outcome. If extraneous variables are not controlled, it cannot be known whether observed changes in the posttest and hence, in groups are due to the experimental treatment or to some extraneous variables. Control refers to the researcher’s efforts to remove, minimize, or hold constant the influence of any variable (extraneous variable) other than the independent variable that might affect performance on the dependent variable. Researchers ensure that the groups are as similar as possible on all confounding extraneous variables and different only on the independent variable so that any difference noted on the dependent variable will be due to the manipulation of the independent variable. Thus, control generally refers to achieve constancy of effect of extraneous variables.

When research participants are randomly assigned to various groups, each participant has an equal probability of being assigned to each group, and the variables they bring with them are also randomly assigned. Therefore, the groups are similar on these variables, and any differences that do exist will be due to chance. Since random assignment controls for both known and unknown variables, therefore it is considered as the best technique for equating the groups on all variables at the start of an experiment and should be used whenever and wherever possible. When random assignment is done, the researcher can claim that changes on the dependent variable are caused by the independent variable that was systematically manipulated by the researcher. Any uncontrolled extraneous variables affecting performance on the dependent variable are threats to the validity of an experiment. An experiment is valid if results obtained are due only to the manipulated independent variable and if they are generalizable to participants or contexts beyond the experimental setting. These two criteria are referred to, respectively, as the internal validity and external validity of an experiment. Therefore, it is very important to control extraneous variables because some of them are threats to internal validity, others are threats to external validity, and some may be threats to both internal validity and external validity of an experiment (Gay, Mills, & Airasian, 2006).
Thus, an experimental study usually involves a comparison of two groups of subjects, an experimental group and a control or a comparison group, although it is possible to conduct an experiment with only one group (by providing all treatments to the same subjects) or with three or more groups. The group that receives the new treatment is called the *experimental group*. The group that receives a different treatment or is treated as usual is called the *control group*. The control group is crucially important in all experimental research, for it enables the researcher to determine whether the treatment has had an effect or whether one treatment is more effective than another.

### 3.1 Population of the Study

Best and Kahn (2006) defined a population as “any group of individuals that have one or more characteristics in common which are of interest to the researcher”. Secondary school students, particularly those studying in class X, from Aligarh, Uttar Pradesh, India constituted the target population of the present research study.

### 3.2 School and Setting

This study was conducted in Ayesha Tarin Modern Public School, a senior secondary school (grades Nursery to Class XII) located in Aligarh district, Uttar Pradesh, India, serving approximately 4500 students. This school is affiliated to C.B.S.E., New Delhi, where the medium of instruction is in English. It is one of the largest senior secondary schools in the district and draws students from a majority of lower, middle and upper class families with a wide range of educational backgrounds. It has a good reputation as far as the academic performance of its students is concerned. As per purposive sampling technique, the investigator selected this school. In other words, this school was purposively selected. The willingness of the administration and teachers to collaborate with the researcher, their interest and readiness to contribute to scientific knowledge, and the school’s technological equipments (particularly, the availability of multimedia projectors and two identical computer labs) were the main criteria in the selection of Ayesha Tarin Modern Public School as the field of study.
3.3 Sample

Sample refers to a small proportion of population selected for observation and analysis. Wiersma (2000) defines sample as “a subset of the population to which the researcher intends to generalize the results”. By observing the characteristics of the sample, one can make certain inferences about the characteristics of the population from which it is drawn as sample is a small representation of the population. Samples are not selected haphazardly rather they are chosen in a systematic way according to some rule or plan so that they are representative of the population.

The subjects of the present study included 210 students who were enrolled in class X (session 2011-12) in Ayesha Tarin Modern Public School, Aligarh, Uttar Pradesh, India. Using a table of random numbers, these students were randomly assigned to 6 sections, each section consisting of 35 students. Further, the three teaching approaches were randomly assigned to these 6 sections in such a way that the 2 sections were subjected to traditional teaching, another 2 sections were subjected to teacher-centered CAI (TCCAI) and the remaining 2 to student-centered CAI (SCCAI). In other words, 2 sections, subjected to traditional teaching, were considered as control group and the remaining 4 sections, subjected to CAI, were considered as experimental groups: 2 sections as teacher-centered CAI experimental group and the remaining 2 sections as student-centered experimental group. Moreover, two teachers were also randomly assigned to these sections so that each teacher had three sections to teach by making use of each type of teaching approach. This was done to minimize teacher differences and bias. Thus, a total of 210 students and 2 teachers (including investigator) were selected as participants for this study.

Table 3.1 provides the group-wise distribution of the sample by showing that each group consisted of 70 students. Figure 3.1 presents the group-wise distribution of the sample by percentage.
Table 3.1

*Group-wise Distribution of the Sample*

<table>
<thead>
<tr>
<th>Group</th>
<th>Sample Size (n)</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Group</td>
<td>70</td>
<td>33.3</td>
</tr>
<tr>
<td>TCAI Group</td>
<td>70</td>
<td>33.3</td>
</tr>
<tr>
<td>SCAI Group</td>
<td>70</td>
<td>33.3</td>
</tr>
</tbody>
</table>

![Figure 3.1 Group-wise Distribution of the Sample](image)

Table 3.2 provides the gender-wise distribution of the participants in the three groups. Control group consisted of 41 male and 29 female students; 42 male and 28 female students constituted the TCCAI group; while the SCCAI group consisted of 43 male and 27 female students, as shown in Figure 3.2.
Table 3.2

*Gender-wise Distribution of the Sample after Random Assignment*

<table>
<thead>
<tr>
<th>Demographic</th>
<th>Control Group</th>
<th>TCCAI Group</th>
<th>SCCAI Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td>Male</td>
<td>41</td>
<td>58.57</td>
<td>42</td>
</tr>
<tr>
<td>Female</td>
<td>29</td>
<td>41.43</td>
<td>28</td>
</tr>
</tbody>
</table>

Figure 3.2 Gender-wise Distribution of Participants in each Group after Random Assignment

3.4 Research Design

Research design may be referred to as the plan, structure and strategy of investigation conceived so as to obtain answers to research questions and control variances (Kerlinger, 1973). Research design refers to the outline, plan, or strategy that is used to answer research questions. Planning a research design means specifying how the participants are to be assigned to experimental and control groups, how to control for potentially confounding extraneous variables, and how to collect and analyze the data (Johnson & Christensen, 2012). The research design therefore enables the researcher to anticipate what the appropriate research decisions should be so as to maximize the validity of results. It is critical that the choice of research design be appropriate to the subject under investigation (Patton, 1987).
In this study, a randomized pretest-posttest control group design (Campbell and Stanley, 1966) was used because it is a true experimental design which controls for nearly all sources of internal and external invalidity. The pretest-posttest control group design requires at least two groups of research participants, an experimental group and a control group, each of which is formed by random assignment; both groups are pre-tested on the dependent variable, each group receives different treatment (independent variable), and both groups are post-tested on the dependent variable at the end of the study. Post-test scores are compared to determine the effectiveness of the treatment. The pretest-posttest control group design may also be expanded to include more than one experimental group (Gay, Mills, & Airasian, 2006), as was done in this study.

For the three groups involved in the present experimental study, randomized pretest-posttest control group design takes the following form:

<table>
<thead>
<tr>
<th></th>
<th>Pretest</th>
<th>Treatment</th>
<th>Posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td>CG</td>
<td>T₁, T₂</td>
<td>Xₐ</td>
<td>T₁, T₂</td>
</tr>
<tr>
<td>EG₁</td>
<td>T₁, T₂</td>
<td>Xₐ</td>
<td>T₁, T₂</td>
</tr>
<tr>
<td>EG₂</td>
<td>T₁, T₂</td>
<td>Xₐ</td>
<td>T₁, T₂</td>
</tr>
</tbody>
</table>

where, CG represents the control group, subjected to the traditional teaching approach (Xₐ); EG₁ represents Experimental Group 1, subjected to the TCCAI approach (Xₐ); and EG₂ represents Experimental Group 2, subjected to the SCCAI approach (Xₐ). T₁ and T₂ represent the Physical Science Attitude Scale (PSAS) and Physical Science Achievement Test (PSAT) respectively.
This design is diagrammatically represented in Figure 3.3.

![Diagram](image)

**Figure 3.3: Diagrammatic Representation of Randomized Pretest-Posttest Control Group Design**

In order to measure students’ attitude towards Physical Science and their achievement in Physical Science, PSAS and PSAT were administered as pre-tests and post-tests respectively to students in all the three groups at the beginning and end of the treatment. CAI Attitude Scale (CAIAS) and CAI Environment Scale (CAIES) were administered only to the students of both the experimental groups (TCCAI and SCCAI) at the end of the treatment, in order to predict their attitude and achievement in Physical Science using CAI Attitude subscales and CAI Environment subscales as predictors.

Thus, in this design, the independent variable was the intervention or treatment (Traditional Teaching, TCCAI, and SCCAI). The dependent variables were post-test scores on PSAS and PSAT respectively. Control variables or covariates were
pre-test scores on PSAS and PSAT respectively. Latent variables were CAI Attitude subscales and CAI Environment subscales, which were used as predictors of attitude and achievement in Physical Science for TCCAI and SCCAI groups.

3.4.1 Rationale for using Pretest-Posttest Control Group Design

The pretest-posttest control group design was used in the present study due to the following reasons:

1. The use of the pre-test provides the researcher with a means of checking whether the two groups are really similar at the beginning of an experiment - that is, whether random assignment actually succeeded in making the groups equivalent. A pre-test is also necessary if the amount of change over time is to be assessed, as was the case in this study (Fraenkel & Wallen, 2012).

2. It is an excellent experimental design because it effectively controls for the eight threats to internal validity originally identified by Campbell and Stanley: history, maturation, testing, instrumentation, regression, selection, mortality, and selection interactions (Gall, Gall, & Borg, 2003).

3. The combination of random assignment and the presence of a pre-test and a control group serve to control for all sources of internal invalidity. Random assignment controls for regression and selection factors; the pre-test controls for mortality; randomization and control group control for maturation; and the control group controls for history, testing, and instrumentation. Instrumentation and testing are controlled because if pre-testing leads to higher posttest scores, the advantage should be equal for both the control and experimental groups (Gay, Mills, & Airasian, 2006).

4. The only weakness in this design is a possible interaction between the pre-test and the treatment. That is, treatment might produce significant effects only because a pre-test was administered. When it is tried on a group which has not been pre-tested, the treatment might not work as well (Gall, Gall, & Borg, 2003). This interaction may affect the external validity of an experiment and thus, may make the results generalizable only to other pretested groups. The seriousness of this potential weakness depends on the nature of the pre-test,
nature of the treatment, and the duration of the study (Gay, Mills, & Airasian, 2006). In this study, this interaction was minimized by the non-reactive nature of the pre-test (numerical problems and chemical equations), and by the duration of the study (8 weeks).

3.4.2 Internal Validity

Fraenkel, Wallen, and Hyun (2012) have identified ten threats to internal validity. In order to control or minimize these threats, they also have suggested certain techniques or procedures which were followed in this study. They are presented in Table 3.3.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Threat</th>
<th>Techniques or Procedures</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Subject characteristics</td>
<td>Random assignment was used. In addition, ANCOVA was conducted to control for the effect of pre-test (used as a covariate).</td>
</tr>
<tr>
<td>2.</td>
<td>Mortality</td>
<td>However, because the loss was the same in all groups, mortality was not a problem.</td>
</tr>
<tr>
<td>3.</td>
<td>Location</td>
<td>Control and TCCAI groups were administered treatments in their respective classrooms throughout the course of the study. SCCAI group was administered treatment in the same computer labs throughout the course of the study.</td>
</tr>
<tr>
<td>4.</td>
<td>Instrumentation</td>
<td></td>
</tr>
<tr>
<td>a.</td>
<td>Instrument Decay</td>
<td>Attitude scales and multiple-choice achievement test were used. They were scored on set standard rules by the investigator.</td>
</tr>
<tr>
<td>b.</td>
<td>Data Collector Characteristics</td>
<td>The groups were administered instruments by their respective instructors at pre-test and post-test stages.</td>
</tr>
<tr>
<td>c.</td>
<td>Data Collector Bias</td>
<td>The instructors were provided with standard procedures for administering the instruments during the training period.</td>
</tr>
<tr>
<td>5.</td>
<td>Testing</td>
<td>Presumably the pre-test would affect all groups equally.</td>
</tr>
<tr>
<td>6.</td>
<td>History</td>
<td>During the course of the study, no unusual events occurred that might affect the groups’ attitudes and achievement in Physical</td>
</tr>
</tbody>
</table>
Random assignment was used. Moreover, the instructors teach each method over the same time period.

To control for any novelty or Hawthorne effect, no special attention was given to any of the groups.

Random assignment was used.

Instructors were trained before administering the treatments.

Each of the two instructors taught students of control, TCCAI and SCCAI groups respectively, that is, each instructor made use of the three instructional methods. Moreover, two observers monitored each of the two instructors, while they were teaching.

3.4.3 External Validity

External Validity is the extent to which the findings of an experiment can be applied to individuals and settings beyond those that were studied. Bracht and Glass (1968) identified twelve factors that affect an experiment’s external validity. These factors arise due to the conventional experimental designs used by educational researchers (Gall, Gall, & Borg, 2003). Snow (1974) criticized conventional experimental design for its artificiality and lack of generalizability. He used the term “systematic design” to characterize the typical form of experimentation. In systematic design, a few treatment variables and pretest-posttest measures are administered. All other variables are either controlled or ignored. The problem with systematic design is that it often produces artificial learning situations and unnatural behaviour in the learner. He advocates instead the use of “representative design” to combat these problems and also to increase the generalizability of findings from experiments. Representative design is a process for planning an experiment so that it accurately reflects both the real-life environments in which learning occurs and the natural characteristics of learners. Snow suggests compromises that can make experiments more representative (Gall, Gall, & Borg, 2003). The following recommendations, given by Snow (1974), were followed in this study in order to minimize the threats to external validity:
1. The present study was conducted in the actual educational setting of a senior secondary school as the investigator would like to generalize the findings of this study to similar environments prevailing in other secondary schools.

2. Since the purpose of this study was to evaluate the relative effectiveness of traditional teaching and two new instructional methods (TCCAI and SCCAI), therefore two instructors were involved in making use of each of the three methods. This situation is quite similar to real situations in schools, where more than one teacher teaches a particular academic subject to different sections of a class.

3. In the present study, not only the respective instructors but also the principal of the school and the investigator’s supervisor observed what students actually were doing during the experiment. These observations were quite helpful in interpreting the results of this study.

4. Participants were properly trained prior to the start of intervention period. Instructors and only students of SCCAI group were trained in using multimedia CAI software.

3.5 Intervention

In the present study, the following three types of teaching formats or intervention (treatment) were adopted in order to study their effects on students’ attitude and achievement in Physical Science:

1. Traditional Teaching

2. Teacher-centered CAI

3. Student-centered CAI

The details of each of these interventions (instructional methods) have been provided in the later part of this chapter.

3.6 Instruments

The following two types of instruments were used in the present study:
1. Intervention Instruments

2. Dependent Measure Instruments

3.6.1 Intervention Instruments

The following instruments were used in the intervention period:

1. Science Textbook for Class X

2. Multimedia CAI Software

3.6.1.1 Science Textbook for Class X

It was published by National Council of Educational Research and Training (NCERT), New Delhi, India and used by all CBSE affiliated schools in India. Although it acted as the standard and basic instrument which was usually consulted by the instructors for each of the groups involved, it was used as the main intervention instrument for the control group. The following four chapters from this textbook were covered during this study:

1. Light – Reflection and Refraction (Physics)

2. Human Eye and the Colourful World (Physics)

3. Acids, Bases, and Salts (Chemistry)

4. Metals and Non-Metals (Chemistry)

3.6.1.2 Multimedia CAI Software

Multimedia CAI Software, developed by the investigator with the help of a computer software expert, was used in this study as an intervention instrument for both TCCA1 and SCCA1 experimental groups. It is a multimedia computer assisted tutorial program. It matches the curriculum content of the tenth grade Science curriculum, prescribed by NCERT, New Delhi, in an orderly and engaging manner. It is a comprehensive system suitable for average and above average students, as well as for those having difficulties in Physical Science. It is an educational tool designed to support class X science teaching and learning activities. This instructional software is
a dynamic creation and investigation tool that enables students to explore and understand science in alternative ways, which is not easy to do with traditional tools.

It was created through consideration of basic teaching methods that respond to the cultural, psychological and cognitive needs of the target population, as well as contemporary teaching and learning methods which help students gain positive attitudes towards Science. Suitable attention was paid to the issues of learner control, feedback, interactivity, and flexibility. A proper sequence of learning materials was established to lead the students to the realization of the required objectives. A learner-controlled strategy was employed so that students were free to begin from any point in the program regarding the subject topics of the unit, and also allowed to go back and forth within the sections of the chapter. Nevertheless, a carefully designed linear route was also built into the program so that any student who preferred instruction scheduled by the computer could easily get it. The program required the students to be active by encouraging them to answer each question. Following their responses to a question, immediate feedback as to the accuracy of their answers was provided. After correct answers, the program provided feedback verifying that the answer was correct, and after wrong answers, the program indicated that the response was incorrect. Feedback and exercises are included at the end of each unit which helps students to evaluate their own knowledge learning.

It included a series of interactive tutorials designed as a stand-alone alternative or supplement to science syllabus for class X. Throughout its instruction, the program was geared specifically towards tutoring students on each and every concept as it covered the various chapters of the prescribed syllabus. These tutorials provided students with opportunities to be tutored on all the topics of the prescribed syllabus. Through use of this software by the teacher, students were introduced to each topic for discussion in class. Students also used it for the purpose of helping them to explore and master each concept and difficult vocabulary. For the purposes of preparing students for monthly tests and examinations, it can be used as a mechanism for reviewing concepts studied already and for self-testing and drill on central concepts. It can also be used for remediation in areas not well-learned.
Students were able to perform the aforementioned tasks as the software offered instruction through the use of text, figures, and videos in addition to simple, engaging animations and simulations. Through the course of instruction, the students were also able to use inductive and deductive skills where appropriate, for example, in going through the process of a simulated experiment. Overall, the software was intended to assist students in mastering tenth-grade Science concepts through a series of interactive tutorials.

3.6.2 Dependent Measure Instruments

The following instruments or tools were used to collect data for this study:

1. Physical Science Attitude Scale (PSAS)
2. Physical Science Achievement Test (PSAT)
3. CAI Attitude Scale (CAIAS)
4. CAI Environment Scale (CAIES)

PSAS, PSAT, and CAIAS were developed by the investigator. PSAT and PSAS were administered to control and experimental (TCCAI and SCCAI) groups prior to the beginning as well as at the end of the intervention period. CAIAS and CAIES were only administered to experimental groups at the end of the intervention period.

3.6.2.1 Physical Science Attitude Scale (PSAS)

A 30-item scale was developed by the investigator to measure the students’ attitudes towards Physical Science (see Appendix D). This scale is Likert-type scale and has five-option choices (Strongly Agree, Agree, Undecided, Disagree, and Strongly Disagree). Cronbach’s alpha reliability coefficient of the total scale was 0.93. It consists of 5 subscales or dimensions, namely, enjoyment, anxiety, confidence, career, and importance of science.

3.6.2.2 Physical Science Achievement Test (PSAT)

Students’ achievement in Physical Science was measured using the Physical Science Achievement Test (PSAT) developed by the investigator (see Appendix F).
The instrument, containing 72 four-option, multiple-choice questions, was developed by the researcher. Four chapters from the textbook Science for class X, published by NCERT, New Delhi, were selected for this study. The test was based on these four chapters: (1) Light - Reflection and Refraction, and (2) Human Eye and the Colourful World (Physics); and (3) Acids, Bases, and Salts, and (4) Metals and Non-Metals (Chemistry). The test was intended to determine the knowledge, comprehension and application levels of students related to the fundamental concepts of Physical Science, and their higher order thinking skills (HOTS) on recalling the relationships between concepts, and applying them to problems. Cronbach’s alpha reliability coefficient of the total test was 0.92.

3.6.2.3 CAI Attitude Scale (CAIAS)

A 30-item scale was developed by the investigator to measure the students’ attitudes toward CAI (see Appendix G). This scale is Likert-type scale and has five-option choices (Strongly Agree, Agree, Undecided, Disagree, and Strongly Disagree). Cronbach’s alpha reliability coefficient of the total scale was 0.92. It consists of 5 subscales or dimensions, namely, content presentation, assessment, individualization, integration, and perceived effectiveness.

3.6.2.4 CAI Environment Scale (CAIES)

This scale was developed by Askar, Koksal, and Yavuz (1991) to assess the perceptions of students about the difference between computer assisted instruction and regular classroom environment (see Appendix H). The scale consists of 17 items, and they are scored on a three-point response scale: Increased (3), Same (2) and Decreased (1) for the positively worded items; the negatively worded items are reversed to a positive direction for scoring purposes. The authors used principal component analysis and identified three factors or subscales labeled as ‘cognitive dimension’, ‘emotional dimension’ and ‘interaction dimension’. They calculated the alpha reliability estimates of the total scale as 0.78 and of the three factors or subscales, which are presented in Table 3.4.
### Table 3.4

**Descriptive Information for Subscales of the CAIES**

<table>
<thead>
<tr>
<th>Subscale Name</th>
<th>Description</th>
<th>No. of Items</th>
<th>Items No.</th>
<th>Cronbach’s Alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cognitive</td>
<td>The extent to which students perceive the cognitive aspects of CAI environment more useful than that of regular classroom</td>
<td>9</td>
<td>1, 2, 3, 7, 8, 9, 13, 14, 15</td>
<td>0.79</td>
</tr>
<tr>
<td>Emotional</td>
<td>The extent to which the students consider their CAI environment more emotionally sound and conducive for learning than that of regular classroom</td>
<td>5</td>
<td>5, 6, 12, 16, 17</td>
<td>0.73</td>
</tr>
<tr>
<td>Interaction</td>
<td>The extent to which students perceive the interaction among students, student-teacher interaction, and help from teacher more appropriate than that of regular classroom</td>
<td>3</td>
<td>4, 10, 11</td>
<td>0.75</td>
</tr>
</tbody>
</table>

#### 3.7 Variables

Variables of this study can be categorized as follows:

**3.7.1 Independent Variables**

The main independent variables were the instructional method (that is, treatment or intervention being implemented) and gender, having three levels (Traditional Teaching, TCCAI, and SCCAI) and gender having two levels (male and female) respectively.
3.7.2 Dependent Variables

The dependent variables were students’ post-test scores on Physical Science Attitude Scale (PSAS) and Physical Science Achievement Test (PSAT) respectively.

3.7.3 Covariates

The covariates were students’ pre-test scores on PSAS and PSAT respectively.

3.7.4 Latent Variables

The latent variables were students’ scores on subscales of CAI Attitude Scale (CAIAS) and CAI Environment Scale (CAIES) respectively.

Besides this, a number of variables, such as grade level (class X) of students, teaching subject (Physical Science) and the equivalent instructional content and duration, were held constant.

Figure 3.4: Variables involved in the study
3.8 Procedures for Data Collection

The procedures for data collection consisted of the following phases which were carried out sequentially in order to complete this study:

3.8.1 Development of Tools

Multimedia CAI software, Physical Science Attitude Scale (PSAS), Physical Science Achievement Test (PSAT), and CAI Attitude Scale (CAIAS) were developed by the investigator, the details of which are given in chapter 4.

3.8.2 Preparatory Phase

(i) Seeking the Principal’s Approval

A formal request was presented to the principal of Ayesha Tarin Modern Public School, Aligarh, Uttar Pradesh, India, for conducting the present research study within school settings. The principal permitted the investigator to conduct the investigation within the school and also allowed her to meet the school’s science faculty members and to observe the structure and facilities of the school’s two

Figure 3.5: Latent Variables used for explaining Variance in Dependent Variables
computer laboratories. After all this, it was then decided that a schedule or timetable would be worked out, between the lab assistants and science teachers as to the periods and days the science classes would be conducted in the classrooms and computer labs respectively (see Appendix I for the principal’s letter).

(ii) Training of Instructors

Once schedules were planned out, suitable arrangements were made for the training of participating teachers or instructors and lab assistants. A staff development workshop was conducted by the investigator with the help of a computer software expert, prior to the start of the study. The principal, intervention teacher, and two computer lab assistants participated in this 4-hour workshop which lasted for six days (40 minutes per day). It focused on the following: (a) research supporting the scope of CAI, (b) curricular components of the multimedia CAI software, (c) administration and scoring of pre-test and post-test, (d) training of students in the SCCAI experimental group, in using CAI software on an individual basis, (e) supplementing traditional teaching with CAI in TCCAI experimental group, (f) instructor’s role in each intervention, (g) sequence and design of the instructional activities, and (h) implementation procedures for each intervention.

The purpose of involving computer lab assistants in this workshop was to familiarize them with the CAI software to be used in this study. The computer software expert told them about the minimum requirements for its installation; how to load, run, and work on it; and some basic trouble-shooting techniques that they could employ in case of some difficulty faced by them, the instructors, or students while using it. They were also given a handout containing all these information.

(iii) Installation of Multimedia CAI software on Computers in Computer Laboratories

The school had two computer labs which housed 37 and 39 networked computers respectively. The CAI software was installed on the master computer. Since all the computers in each lab were well-connected with one another via LAN, therefore CAI software could be accessed from any individual computer.
(iv) **Assignment of Participants to Control and Experimental Groups**

Using a table of random numbers, 210 students, enrolled in class X were randomly assigned to 6 sections; each section consisting of 35 students. Further, the three teaching approaches were randomly assigned to these 6 sections in such a way that the 2 sections were subjected to traditional teaching, another 2 sections were subjected to teacher-centered CAI and the remaining 2 to student-centered CAI. In other words, 2 sections, subjected to traditional teaching, were considered as control group and the remaining 4 sections, subjected to CAI, were considered as experimental groups: 2 sections as teacher-centered CAI experimental group and the remaining 2 sections as student-centered experimental group. Moreover, two teachers were also randomly assigned to these sections so that each teacher had three sections to teach by making use of each type of teaching approach.

**3.8.3 Pre-test Phase**

PSAS and PSAT were administered as pre-tests to students of all the groups three and two days prior to the intervention respectively by their respective instructors. The purpose of pre-testing was to account for any differences in students’ attitudes and achievement that may have existed prior to beginning of the study.

To assure reliability of the instruments used, identical testing conditions were created for all groups at pre-test phase. Students were administered the instruments during their regular Physics or Chemistry class periods, under the same conditions of temperature and lighting. To ensure reliability in scoring the instruments, the researcher created a set of scoring standards. The scoring of these instruments for all the groups was done by the investigator using the standards created beforehand.

**3.8.4 Intervention Phase**

Treatments or interventions were conducted for a period of 8 weeks for all the groups. They attended six periods per week (4 hours per week). Each period was of 40 minutes duration. Six periods were allotted to these groups for learning Physical Science; three periods each for Physics and Chemistry on alternate days of the week. They learnt and completed the following four chapters of Physical Science (two each in Physics and Chemistry) during these 8 weeks. To verify whether the intervention occurred as planned, the school principal as well as supervisor of the investigator
went to each class and observed the instructional activities of each group during each intervention session. Moreover, instructors also monitored students’ activities in order to check whether they were attentive and doing their work properly.

Thus, care was taken to ensure that an appropriate comparison was attained among the three instructional approaches. All the groups were taught four hours a week, followed the same instructional sequence, and received the same instructional materials, the same hands-on activities, and the same assignments. They also had the same learning objectives, and had equal opportunities to practise their learning objectives. Therefore, not only was the scope of the content covered by the three treatments deemed equivalent relative to the post-test but also was students’ invested time on the instructional materials controlled among these three groups for this study.

3.8.4.1 Intervention in the Control Group

The control group was subjected to traditional teaching without any exposure to multimedia CAI software. This teaching approach emphasized direct lectures given by teachers, interactive discussions between the teacher and students, use of textbook materials, and clear explanation of important concepts to students, but no use of multimedia CAI software. The teacher for the most part assumed the role of the “provider” of information and undertook the task of transferring science knowledge to students.

3.8.4.2 Intervention in the TCCAI Experimental Group

The TCCAI scheme in the current study was a mixture of whole-class presentation, interactive discussions between the teacher and students, and classroom activities using the multimedia CAI software. The instruction emphasized direct guidance, lectures, and presentation, occasional demonstrations, and clear explanations of important concepts to the students given by teachers in the lecture classrooms. The whole-class presentation was implemented using a combination of a laptop computer and a projector to display the contents of the multimedia CAI software on a large screen in front of the whole class. Besides, class discussions between the teacher and the students and sometimes, among students were also embedded in this teaching format. It is noted that the whole-class presentation was
intended to be interactive in nature in order to ensure maximum involvement in interactive discussions between the teacher and the students. Although the teacher was an authority and the focus of attention who delivered instruction, students actively participated in the teacher-guided discussion, volunteered their ideas to questions, and asked questions about the content.

3.8.4.3 Intervention in the SCCAI Experimental Group

On the very first day of intervention, the instructors gave SCCAI experimental group an introduction on how to work on the multimedia CAI software and complete different parts of a CAI lesson. This group was also given a handout which listed guidelines on how to use the CAI software. The SCCAI approach stressed students’ self-paced learning using the multimedia CAI software with their own individual computers (PCs) in a modern computer lab. In this approach, the teacher made use of mini lectures to introduce the key concepts about Physical Science and simply presented the contents in the beginning of a class period for about 15 minutes. After this, the students were left to work alone, with minimal interference from the teacher who was present only either to respond to doubts and questions raised by individual students or to provide support and guidance to those who asked for help. The students could freely navigate through a variety of learning sections and acquire their own knowledge and understandings about the various concepts of Physical Science via guided directions provided by the software or the classroom teacher.

3.8.5 Post-test Phase

After the intervention period, the students in the control and experimental groups were administered the same PSAS and PSAT as post-tests by their respective instructors. CAI Attitude Scale (CAIAS) and CAI Environment Scale (CAIES) were only administered to TCCAI and SCCAI experimental groups at the end of the intervention period. Post-test administration and scoring procedures for these instruments were the same as those used for the pre-tests.

3.9 Data Analysis

The raw scores obtained directly after scoring the scale and test booklets constituted simply a long list of numbers without any order. Therefore, in order to
make meaningful interpretation and draw conclusions, raw scores were reorganized, subjected to appropriate statistical analysis and summarized. This was achieved using MS Excel 2007 and SPSS 16.0. Quantitative data were collected and analyzed according to parametric statistical procedures using SPSS 16.0. Parametric statistics are used for group comparison when the researcher can assume that the population is normally distributed, has homogeneity of variance within different groups, and have data that are interval or ratio in scale (McMillan & Schumacher, 1997). The parametric tests used in the data analysis for this study are the t-test, ANOVA and ANCOVA. The t-test is commonly used to determine the level of significance when two means are compared. The t-test for independent samples is used to compare means between two groups and the paired t-test is used to compare pre- and post-measurements within the same group. The analysis of covariance (ANCOVA) is a parametric statistical procedure that adjusts initial group differences based on the correlation between the dependent variable and another variable, called a covariate. Unlike the t-test, the ANCOVA adjusts for pre-existing differences, however smaller, among groups and thereby increases the likelihood of finding a significant difference between group means (Huck & Cormier, 1996).

The researcher tested for statistically significant differences among the three groups on pre-intervention attitudes toward Physical Science, pre-test Physical Science achievement, post-intervention attitudes toward Physical Science, and post-test Physical Science achievement. Within each group, the students’ attitudes toward Physical Science and Physical Science achievement were also assessed to determine if any statistically significant change occurred over the course of eight weeks among the students who received the same type of instruction.

Analysis of Variance (ANOVA) was used to determine if there was a statistically significant difference between the experimental and control groups’ attitude towards Physical Science, as measured by the Physical Science Attitude Scale (PSAS). This pre-intervention analysis was conducted to establish whether the three groups had similar attitudes toward Physical Science at the start of the study. A paired t-test was used to determine if there was a statistically significant difference between the pre- and post-intervention attitude scores towards Physical Science for each of the three groups. These analyses were conducted to establish that a
measurable amount of change occurred within the control and experimental groups during the intervention that was relative to attitude towards Physical Science. Analysis of Covariance (ANCOVA) was used to determine whether a significant difference would be found between group means on attitude towards Physical Science for the experimental and control groups when pre-existing differences were controlled. The dependent variable was the post-intervention attitude scores towards Physical Science and the covariate was the pre-intervention attitude scores towards Physical Science for the student subjects in each of the three groups.

ANOVA was used to determine if there was a statistically significant difference between the experimental and control groups’ achievement in Physical Science, as measured by the pre-test. This pre-test analysis was conducted to provide baseline data for establishing whether the three groups were similar with respect to achievement in Physical Science at the start of the study. A paired t-test was used to determine if there was a statistically significant difference between the pre- and post-test achievement scores in Physical Science for each of the three groups. These analyses were conducted to establish that a measurable amount of learning occurred within the experimental and control groups as a result of the particular method of instruction each group received during the intervention. (It was also relevant to this study to determine whether learning did occur to a measurable degree within each of the groups. For this purpose, paired t-tests are appropriate for comparing pre- and post-test measurements on the same subjects within each of the control and experimental groups.) In order to determine significant differences between pre-test and post-test results of attitude and achievement, a paired t-test was used to analyze pre-test and post-test mean scores for the experimental and control groups. ANCOVA was used to determine whether a significant difference would be found between group means on Physical Science achievement for the experimental and control groups when pre-existing differences were controlled. The dependent variable was the post-test achievement scores in Physical Science and the covariate was the pre-test achievement scores in Physical Science for the student subjects in each of the three groups.

Multiple regression analysis was performed to determine the proportion of variance in attitude and achievement in Physical Science respectively as explained by
the subscales of CAIAS (which were the latent variables and used as predictors in this study). Similarly, multiple regression analysis was performed to determine the proportion of variance in attitude and achievement in Physical Science respectively as explained by the subscales of CAIES (which were the latent variables and used as predictors in this study).

3.10 **Statistical Techniques Employed**

The investigator employed the following statistical techniques suitable for analyzing the quantitative data in accordance to the nature of variables involved and the objectives of the study:

- Item analysis using Pearson’s Product Moment Correlation
- Determination of reliability and validity of tools developed by the investigator, namely, PSAS, PSAT, and CAIAS
- Computation of mean and standard deviation
- Independent samples $t$-test to see the significant difference between two means
- Paired-samples $t$-test

A paired-samples $t$-test is used when the data is collected from only one group of people on two different occasions or under two different conditions. Pretest-posttest experimental designs are an example of the type of situation where this technique is appropriate (Pallant, 2011). Since the present study involved a pretest-posttest control group design, therefore the paired-samples $t$-test was used to compare means for groups of scores that were obtained by making repeated measurements on the same group of participants whose performance on the dependent variable were assessed at two times (i.e., pre-test and post-test).

- Analysis of Variance (ANOVA)

It is a statistical analysis that tests whether there are statistically significant differences between group means on scores on a quantitative dependent variable across two or more groups (Warner, 2008). It compares the variance (variability in scores) between the different groups (believed to be due to the independent variable)
with the variability within each of the groups (believed to be due to chance or errors). The test statistic, an F ratio, represents the variance between the groups divided by the variance within the groups (Pallant, 2011).

In this study, factorial ANOVA (two-way ANOVA) was used. Factorial ANOVA is the statistical method that analyzes the independent or main and interaction effects of two or more independent variables on a dependent variable (Kerlinger, 1973).

- Analysis of Covariance (ANCOVA)

It is a form of analysis of variance that tests the significance of the difference between means of final experimental data by taking into account the correlation between the dependent variable and one or more covariates, and by adjusting initial mean differences in the experimental groups. That is, ANCOVA analyzes the differences between experimental and control groups on dependent variable Y after taking into account initial differences in the Y measures (i.e., pretest measures) or differences in some pertinent independent variable. The measure used for the control (pretest measures or measures on a pertinent independent variable) is called the covariate (Kerlinger, 1973).

According to Field (2009), there are two reasons for including covariates in ANOVA:

*Elimination of confounds:* In any experiment, there may be unmeasured variables that confound the results (i.e., variables that vary systematically with the experimental manipulation). If any variables are known to influence the dependent variable being measured, then ANCOVA is ideally suited to remove the bias of these variables. Once a possible confounding variable has been identified, it can be measured and entered into the analysis as a covariate.

*To reduce within-group error variance:* ANCOVA is used to reduce within-group error variance by allowing the covariate to explain some of this error variance. However, for this to be true the covariate must be independent from the experimental effect. Therefore, before running the ANCOVA, it should be checked that the independent variables and covariate(s) are independent. It can be done by using
ANOVA or a $t$-test to check whether the groups differ significantly on the covariate. If they do not significantly differ, then only covariate should be included in analysis because in this situation, the covariate shares its variance only with the one that is currently unexplained and is completely independent from the treatment effect. This scenario is the only one in which ANCOVA is appropriate (Field, 2009).

- **Effect size (that is, Partial Eta Squared, $\eta^2$)**

It assesses the proportion of variance in dependent variables (attitude and achievement in Physical Science at post-test stage) that is predictable from independent variables (instructional method and gender) and covariate when the variance associated with other predictors or independent variables has been partialled out or removed.

- **Post hoc Tests**

A significant $F$ test indicates that the group means are significantly different. It does not, however, tell us which of the groups differ from one another. For this, post hoc tests need to be conducted. In this study, post hoc tests were conducted using Bonferroni’s test. It consists of pairwise comparisons that are designed to compare means of all different combinations of the treatment groups. Pairwise comparisons control the familywise error by correcting the level of significance for each test such that the overall Type I error rate ($\alpha$) across all comparisons remains at .05. In Bonferroni correction, $\alpha$ is divided by the number of comparisons, thus ensuring that the cumulative Type I error is below .05. Bonferroni’s test controls the Type I error rate very well and has more power when the number of comparisons is small (Field, 2009).

- **Multiple Regression**

Multiple regression analysis is a method for studying the effects and the magnitudes of the effects of more than one independent variable on one dependent variable using principles of correlation and regression (Kerlinger, 1973). In multiple regression, more than one independent variable is included in an equation to predict scores on a quantitative dependent variable (Warner, 2008).
Multiple regression analysis was performed in this study to determine the proportion of variance in the dependent variable as explained by the independent variables (predictors). It was also intended not only to find out the combined effect of independent variables but also the individual effect of each independent variable on the dependent variable. Therefore, in this study, a standard multiple regression method was used in which all independent variables are entered into the equation at one step, and the proportion of variance uniquely explained by each independent variable is assessed while statistically controlling for all other independent variables (Warner, 2008).